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Volume 2. Appendices

Hittman Associates, Inc, Columbia, MD

Prepared for

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16. ABSTRACT This volume of the report contains appendices supporting the Volume 1 discussion of the environmental effects of the multimedia waste streams from a standard Solvent Refined Coal liquefaction facility. It provides information on the methodologies involved, including Multimedia Environmental Goals (MEGs) and Source Analysis Methodology (SAM). It also summarizes the 1977 amendments to the Clean Air, Clean Water, and Hazardous Waste Acts. The report provides a compilation of site-specific information as background for the pollutant effects study results given in Volume 1.

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Liquefaction	Boilers	Solvent Refined Coal	07D	
Emission	Sulfur	Synthetic Fuels		07B
Waste Disposal	Processing	Sulfur Recovery		13H
Fuels	Leakage	Fugitive Emissions		
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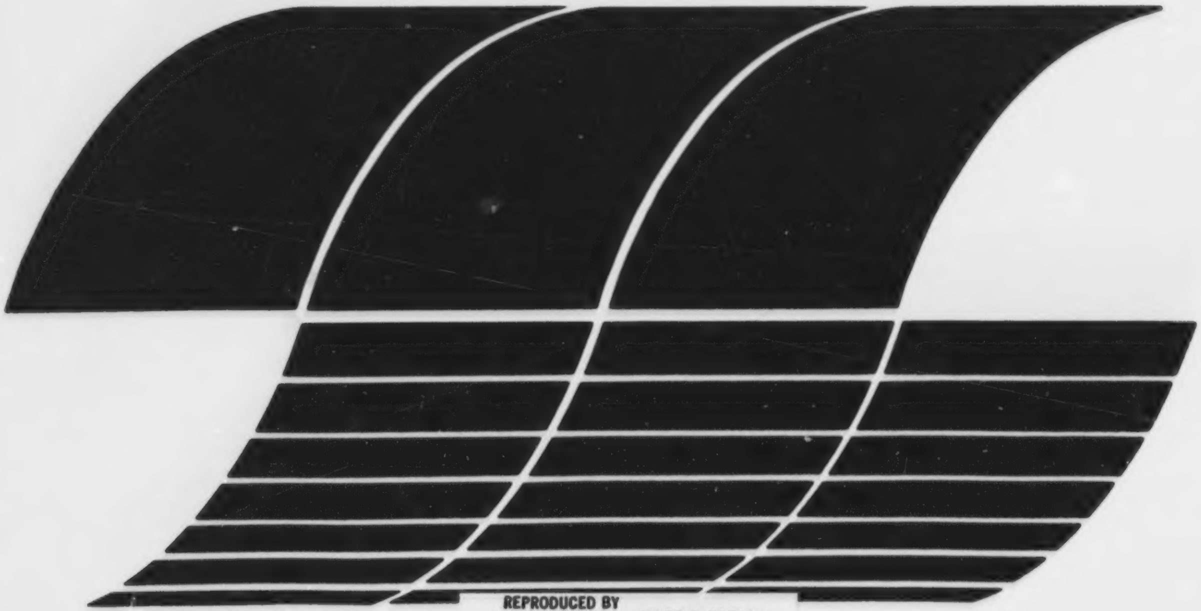

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SRC Site-Specific Pollutant Evaluation;
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by

Homer T. Hopkins, Kathleen M. McKeon, Carolyn R. Thompson,
and E. Earl Weir

Hittman Associates, Inc.
9190 Red Branch Road
Columbia, Maryland 21045

Contract No. 68-02-2162
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EPA Project Officer: William J. Rhodes

Industrial Environmental Research Laboratory
Office of Energy, Minerals, and Industry
Research Triangle Park, NC 27711

Prepared for

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APPENDIX I

MULTIMEDIA ENVIRONMENTAL GOALS FOR ASSESSMENT: AN INTRODUCTION

A-I MULTIMEDIA ENVIRONMENTAL GOALS FOR ASSESSMENT

A-I.1 The MEG Approach (1,2)

Multimedia Environmental Goals (MEGs) are levels of significant contaminants or degradants (in ambient air, water, or land, or in emissions or effluents conveyed to the ambient media) that are judged to be (1) appropriate for preventing certain negative effects in the surrounding populations or ecosystems, or (2) representative of the control limits achievable through technology. MEGs are currently projected for more than 650 pollutants. Unfortunately, only 200 pollutant MEGs were completed at the time this report was written. This list, to be expanded and revised as emergent data warrant, was compiled on the basis of descriptions in the literature of fossil fuels processes and of hazardous substances.

Both Ambient Level Goals and Emission Level Goals based on ambient factors are addressed in the MEGs. Existing or proposed federal standards, criteria, or recommendations are acknowledged as previously established goals and have been utilized wherever applicable. For those substances not addressed by current guidelines, empirical data indicating (1) toxic potential, (2) reactions and associations of the substance within the various media, (3) natural background levels, and (4) conditions under which the substance may be emitted and dispersed have been utilized for the purpose of describing MEGs.

The MEG work represents an important step in EPA's efforts to address systematically many chemical substances for the purpose of establishing priorities for environmental assessment programs. By establishing MEGs, a solution is offered for a ranking system to provide decision criteria in source assessment. The MEGs may also be used for establishing priorities among the pollutants to be ultimately addressed by regulations, and thus may influence control technology development in the future. There are numerous gaps within the current MEGs. These gaps result from either the nonexistence of required data, or its existence in other than the readily available literature.

The MEGs can be put to use by environmental assessors including engineers, chemical analysts, toxicologists, industrial hygienists, system modeling experts, and inspectors or plant monitoring personnel. They can be used as a manual or workbook as they stand, and future supplements will augment this type of application. The MEGs offer a beginning for goals that address pollutant hazards for a large number of substances, establishing a baseline of information presented in summary form. Continued research and reviews are obviously necessary to fill the many information gaps that still exist.

A-I.1.1 Discussion of the MEG Chart

The MEGs are presented in chart form. An example of a MEG chart is found in Figure A-II-1. A more detailed discussion of the MEG chart is found in Appendix A-II.

Emission Level Goals are part of the MEGs and are presented in the top half of the MEG chart. Emission Level Goals are levels of contaminants in point source or fugitive environmental discharge which are thought to be tolerable in that they will probably cause no significant environmental harm. Discharge streams addressed by Emission Level Goals may be gaseous, aqueous, or solid in nature. Emission Level Goals for chemical contaminants may be described on the basis of technology factors or ambient factors. Technology-based Emission Level Goals have not been addressed by the current MEGs, hence the remainder of the discussions in this section will focus on Emission Level Goals based on ambient factors.

Five specific criteria for Emission Level Goals based on ambient factors have been included in the MEG methodology. These are (1) Minimum Acute Toxicity Effluents (MATEs) based on human health effects, (2) MATEs based on ecological effects, (3) Ambient Level Goals based on human health effects, (4) Ambient Level Goals based on ecological effects and, (5) concentrations representing Elimination of Discharge (EOD).

The MEG values are intended to serve both as relative hazard indicators and as estimated absolute indicators of levels of contaminants in waste streams that will prevent serious acute toxic effects. As such, the values should serve a useful purpose for those involved in environmental assessment by furnishing emission-level goals, potential environmental hazard levels, and ultimately control technology goals.

In general, MATEs are derived from estimations of hazards to human health or to ecology induced by short-term exposure to pollutants in waste streams (less than 8 hours per day). In addition to a relative hazard indicator, the MATEs are intended to serve as an estimate of levels of contaminant considered to be safe for short-term exposures. The MATE values should provide an increasingly useful tool for comparisons in environmental assessment.

Ambient Level Goals are concentrations of pollutants in waste streams which, after dispersion, will not cause the level of contamination in the ambient media to exceed a safe continuous exposure concentration. They are derived from three distinct data sources: (1) the most stringent current or proposed federal ambient standards or criteria, (2) empirical data concerning the adverse effects of chemical substances on human health and ecology, and (3) a system relating the carcinogenic or teratogenic potential of specific chemical substances to media concentrations considered to pose an acceptable risk upon continuous exposure.

Elimination of Discharge (EOD) levels are concentrations of pollutants in waste streams which, after dilution, will not cause the level of contaminant to exceed levels measured as "natural background."

For estimating goals for emission levels, the methodology developed was designed to make use of (1) the concentrations described as ambient level goals based on hazards posed to public health and welfare as a result of long-term or continuous exposure to emissions, (2) natural background levels which provide goals for elimination of discharge, and (3) hazards to human health or to ecology induced by short-term exposure to emissions. The need is clear for further research and development of simple but effective models incorporating data pertinent to (1) quality of the receiving media before introduction of the substance, (2) characteristics of transport and dispersion of emissions, (3) considerations of location and abundance of sources emitting a given pollutant, (4) number of population groups affected, and (5) secondary pollutant formations.

A-I.1.2 Derivation of the MEGs

MATE and Ambient Level Goal values that serve as Emission Level Goals are derived by multiplication factors which translate empirical data for each specific chemical substance into concentrations describing minimum acute toxicity concentrations. The rationale behind the numerical value of each of the factors is described in Reference 1. A complete discussion of the mathematical manipulations, including the numerical values of the factors described, can be found in Appendix A-II.

The use of mathematical formulas for translating animal toxicity data into Ambient Level Goals or MATEs requires that certain assumptions be made. A worst-case approach has been taken to keep the MEG values conservative.

The laboratory or empirical values on which the MATEs and Ambient Level Goals are based include: the LD_{50} (usually oral for rat or from a source which can be converted to an oral, rat LD_{50}); Threshold Limit Values (TLVs) established by the American Conference of Governmental Industrial Hygienists (ACGIH); NIOSH recommendations; lowest effective dose causing plant damage; lowest lethal dose reported for a species/route combination (LD_{Lo}); lowest lethal concentration for 50 percent of the exposed organisms (LC_{50}); lowest dosage reported to result in a specified response (TD_{Lo}); lowest lethal concentration reported (TL_m); lowest concentration which was found toxic to any organism (LC_{Lo}); lowest toxic concentration reported to result in a specified response (TC_{Lo}); lowest fish tainting level; and laboratory or epidemiological evidence regarding carcinogens, mutagens, or teratogens. In this discussion, "dose" refers to the amount of a substance taken internally, while "concentration" refers to ambient levels. It is understandable that some readers may question the reliance on TLVs in the methodology developed for describing MEGs. The TLVs and the NIOSH recommendations represent the opinions of experienced physicians, toxicologists, and industrial hygienists regarding safe levels for workroom contamination. However, these judgments are not infallible. The ACGIH has made clear its intention that the TLVs are to be used solely in the practice of industrial hygiene; it does not recommend their use as a relative hazard index or in continuous exposure applications. However, because the TLVs comprise the most comprehensive body of recommendations currently available regarding levels of human exposure to chemical contaminants, and are widely accepted as valid indicators of permissible levels for occupational exposure in the continuing absence of data more reliable than the TLVs, their use in the MEG methodology, balanced as it is by consideration of such a wide array of other factors, is justified.

Estimation of the Ambient Level Goals and MATEs for "zero threshold pollutants" is difficult. Zero threshold pollutants are defined as substances that affect genes such as carcinogens, mutagens, and some teratogens (collectively called genotoxins). There may be no concentration of these compounds for which a no-effect response exists. In other words, a "single hit" by a single molecule of one of these compounds at a single specific cellular site may result in carcinogenesis, mutagenesis, or teratogenesis. An acceptable level for one of these compounds is usually considered to be one such that the chance of a specific hit is so low that the incidence of carcinogenesis, teratogenesis, or mutagenesis will not be significantly increased (at the 95 percent level) over the situation in which the compound is not present. In other words, at the 95 percent level of statistical significance, the rate of carcinogenesis, mutagenesis or teratogenesis would quite probably be less than or equal to 1.05 times the rate when no genotoxin is present. The chance of a "single hit" at a specific site by any one particular chemical is dependent on the availability of the site to that chemical, and the reactivity of that chemical at the site. The factors influencing the availability of the site to the chemical range from stereochemical considerations of the site and the chemical, to the route and efficiency of absorption of the chemical into the organism. The routes and efficiencies of absorption of chemicals are dependent on the form and availability of the chemical to the organism, and the general health and nutritional status of the organism. Thus, the potency of chemical genotoxins differs greatly. Unfortunately, the LD_{50} and other acute toxic parameters discussed previously give no indication of the carcinogenic, mutagenic, or teratogenic effects of a compound. Thus, the Ambient Level Goals for genotoxins must be based on parameters which are different from the toxicological parameters discussed previously.

Ambient Level Goals for genotoxins based on genotoxic effects are derived from a model which translates adjusted ordering numbers, based on a ranking system for suspected carcinogens, into permissible air concentrations. The system for establishing adjusted ordering numbers is a refinement of an ordering plan developed by the EPA Office of Toxic Substances, and reported in An Ordering of the NIOSH Suspected Carcinogens List Based on Data Contained in the List (1). EPA's ordering plan resulted in the assignment of four-digit ordering numbers (hereafter referred to as EPA-NIOSH ordering numbers) for all those substances entered in the NIOSH Suspected Carcinogens List. The numbers assigned to the EPA plan are an "indication of the relative degree of concern that might be warranted for a particular substance regarding its possible carcinogenic potential." It is not appropriate, however, to conclude that all the substances which are assigned a number are carcinogenic.

A-I.1.3 Apparent Reliability of MATE, EPC, and EOD Values

The ultimate Emission Level Goal is to limit contaminant levels in waste streams to the extent that natural background concentrations in ambient media will not be increased. This would mean that the emission concentration for a particular contaminant (with appropriate dilution factors applied) should not significantly exceed the level of that contaminant in ambient air, water, or land, measured in areas containing only natural background concentrations (i.e., no anthropogenic contamination). Concentrations appearing in the column designated EOD under Emission Level Goals are reported levels of chemical species in rural atmosphere, surface waters, or typical soils. Where these concentrations are not reported, levels measured in urban or industrial atmosphere and in drinking water, groundwater, or seawater may be listed, since they give at least some indication of background concentrations.

Figures A-II-2 and A-II-3 of Appendix II give the impression that the MATEs and Ambient Level Goals are based on very little actual data. In reality, very little data exist, except as listed in these figures, which can be applied to the environment. This state of affairs arises from the fact that meaningful experiments are difficult to conceive, expensive to carry out, and time consuming.

A few general comments are required to permit some perspective on the methodology for determination of the MATE and Ambient Level Goal. First, all modeling schemes require that certain assumptions be made and a worst-case approach has been taken to keep the MEG values conservative. In some instances, arbitrary constants are incorporated in an effort to correlate the various sets of Ambient Level Goals and

MATEs. Efforts have been made to incorporate judgments of others relative to the levels of pollutants safely tolerated by human beings.

It should be emphasized that the MATE and Ambient Level Goal concentrations derived through this methodology are based on the empirical data presently available in general secondary references. Time limitations precluded a thorough search of the literature pertinent to each specific compound. It is certain that many of the values will be eventually revised, especially as data gaps are filled. In light of the general nature of the references used, some qualifications should be made regarding the reliability of the MATE and EPC values.

(1) Information reported in the NIOSH Registry of Toxic Effects of Chemical Substances (3) has been used extensively in calculating MATEs. NIOSH, in compiling the Registry, has made no attempt to report the numbers of animals tested, quantity or site of tumors produced in carcinogenicity studies, or precise conditions under which the data were obtained. The level of confidence to be associated with toxicity data such as LD_{50}, LD_{Lo}, TD_{Lo}, LC_{50}, or LC_{Lo} is heavily dependent on this information. It follows that the level of confidence to be associated with MATEs, based on information from the NIOSH Registry (3), is also imprecise.

(2) LD_{50} values may vary widely for a given compound in relation to species, sex, and age of the animals tested, the route of administration of the toxicant, and other test conditions. Because they are available for most compounds, oral LD_{50} values

have been employed rather than LD_{50} values derived from other routes of administration. While this procedure allows for consistency in the calculations, obvious complications involved in the use of oral LD_{50} arise (e.g., differences in the oral absorption factors among the various chemical substances). Oral LD_{50} values also do not take into account different absorption rates across lung epithelium or skin. However, oral LD_{50} values are certainly desired over LD_{50} values obtained from injection when the possible environmental impact of a compound is being considered.

(3) LC_{50} or TL_m values for aquatic life reported in the NIOSH Registry as well as in other sources, indicate lethal concentrations of toxicants for a specific laboratory test procedure. The numbers are greatly dependent on conditions of the test such as: species of aquatic life monitored, static or flow-through conditions, temperature, pH, and the presence of additional toxicants. The lowest LC_{50} values reported in the data base underlying this report were used in the calculations of ecology-based MATEs for water. Extension of the data base will probably yield additional, possibly lower, LC_{50} values representing more sensitive species.

(4) No consideration has been given to additive effects from simultaneous exposure through different media; in addition, synergistic and antagonistic effects have not been incorporated in describing MATE values.

Table A-II-2 of Section II of this appendix shows the reduction of toxic effects of one trace element by another. Table 122, UNADJUSTED RATIOS OF PREDICTED TO OBSERVED LD_{50} VALUES OF 350 PAIRS OF CHEMICALS MIXED 1:1 BY VOLUME, of reference (4) shows the synergistic or antagonistic effects of one organic compound on the action of another. Table A-II-3 of Appendix II shows the increase of toxic effects of one trace element by another. These tables demonstrate that the interaction between pollutants may be quite significant, but not always predictable.

(5) It is recognized that carcinogens react biologically in a number of different ways, and the incidence of synergisms, cocarcinogenicity, promotion, and metabolic alterations into more or less active metabolites cannot be resolved in the scheme employed here for describing MATEs for suspected carcinogens. Also, the role of cocarcinogens which may be present in the effluent streams is not addressed.

(6) The possibility of a metabolite or combustion product from an innocuous substance being an environmental hazard has not been addressed.

MATEs and EPCs for substances not addressed specifically by either TLVs or available toxicity data are in some cases based on data pertinent to a related substance or group of compounds (i.e., having a common parent element). In these cases, appropriate adjustments for molecular weight are made, or where the parent element is of most concern, this will be indicated. For example, the air, health MATEs for all antimony compounds (except antimony trioxide) are

500 $\mu g/m^3$, as Sb, based on the TLV for antimony and antimony compounds, as Sb. The MATE for antimony trioxide has a different basis because of its association with cancer.

While the limitations described above must be emphasized, benefits from the preliminary tabulation of Minimum Acute Toxicity Effluents will still be realized by those involved with environmental assessment. The methodology developed should provide preliminary decision criteria for emerging systems from other projects exploring methodologies for environmental assessment. At the very least, the concept of MATEs should generate further comments on possible applications for the system, as well as suggestions for refining the models used to calculate MATEs and Ambient Level Goals.

A-I.1.4 MATEs for Totals

MATE values for specific chemical contaminants, although valuable, are not sufficient to characterize an environmentally acceptable emission stream. Ceiling values for certain totals associated with gaseous, aqueous, or solid waste emissions are also required. Such totals are to be used in conjunction with the MATEs for specific chemical contaminants and provide a secondary check for effluent contaminant levels.

A-I.1.5 Application of the MEGs

A system has been developed for assigning indicators to designate potentially hazardous substances based on values generated by the MEG methodology. This system provides one simple means of identifying through cursory inspection those pollutants most likely to pose a human threat. All substances which have been ranked are found in Table A-II-5 of Appendix II.

A-I.1.6 MEG for Non-Chemical Pollutants

Cornaby and coworkers (2) report that non-chemical pollution factors such as heat, noise, microorganisms, and land usage can be adapted to the MEG approach. They also report that complex effluents (i.e., entire waste streams) should be amenable to the MEG approach. Other factors such as radionuclides, electromagnetic radiation, and water usage may also be amenable to the MEG approach. The levels as recommended by these authors are found in Appendix II.

A-I.2 Source Analysis Models (5)

The Source Analysis Models (SAMs) are a methodology which allows the quick identification of possible problem areas where the suspected pollutant exceeds the MEG. The SAM format focuses on each separate waste stream which arises during energy production by industrial processes. Such streams may exist because of the process itself, or because of the application of pollution control technology to a process-generated stream.

SAMs, as currently envisioned, address source identification and goal comparison questions; MEGs, by definition, address goals. Various members of the set of SAMs will provide rapid screening, intermediate, or detailed approaches to relate effluent stream pollutant emission levels to the MEGs. Later members of the sequence of SAMs will couple to techniques for effluent transport and transformation analyses. Together they are intended to provide a coarse screening of effluent stream impact for use in environmental assessments.

This discussion describes the rationale and framework of the simplest SAM, the SAM/IA. This SAM is designed for rapid screening with no effluent transport and transformation analysis. Rapid screening of the degree of hazard and the rate of discharge of toxic pollutants may occur at any level or depth of chemical and physical analysis.

In the SAM/IA, waste streams from any process or applicable controls are not assumed to interact with the external environment (i.e., transport of the components in the waste stream to the external environment occurs without transformation of these components). No assumption is made about pollutant-specific dispersion from the source to a receptor. It is assumed, however, that such dispersion would, in almost all cases, be equal to or greater than the safety factors normally applied to acute toxicity data to convert them to estimated safe low-level, longer-term chronic ambient exposure levels.

SAM/IA thus:

- Is on a waste stream concentration basis
- Uses only one potential assessment alternative (the MATE)
- Does not include transport/transformation analysis
- Includes only degree-of-hazard/toxic-unit discharge calculations.

Such rapid screening requires understanding of the assumptions being made. These assumptions include:

- The approximately 650 substances currently in the MEG list, or soon to be added, are the only components of a waste stream which have been addressed at this time. Unknown components may be sources of environmental impact which are modified or modifiable by the control technology. Therefore, Level 1 bioassay results will be important as a companion data base for interpretation of SAM/IA results.

- Dispersion of effluents will be adequate and will also offset any transformation to more toxic substances.

- The MATE values (or the basic data on which they are based) are a good set of criteria.

- No synergistic or non-additive effects are considered. The bioassay results are an important aid to interpretation of this point.

These assumptions are built in to SAM/IA. No provision has been made for modification of the SAM/IA calculation method for specialized circumstances. In many cases, perhaps most, the assumptions are conservative. However, these factors should be kept in mind in evaluating the need for more detailed assessment.

In SAM/IA, major simplifying assumptions have been made about pollutant transport and transformation in the environment prior to impact on a receptor. The criteria against which pollutant concentrations are judged have also been subject to simplifying assumptions. As a result, SAM/IA is designed for use by experienced and qualified project officers and environmental assessment contractor personnel who will, on a case-by-case basis, review these assumptions to ensure the correct application of the model. In addition, at the time of this report, many pollutants exist for which MATEs have not yet been established. The user must, therefore, exercise judgment in flagging these omissions and bringing them to the attention of the EPA in terms of:

- Their importance to the particular environmental assessment being conducted
- Requirements for the continuing development of additional MATE values.

A-I.2.1 SAM/IA Format

SAM/IA has two forms on which to enter and process data. On the first, each process is analyzed into component effluent streams. Then, for each such stream, a second form is used to compare each pollutant in each stream against an environmental goal, and to sum over all such comparisons to determine the degree of hazard which this stream poses. A slightly different second form is used for Level 1 than for Level 2 analysis. Further entries on the first form then allow summation of the degree of hazard over all gas, liquid, or solid waste streams. As an example, a SAM/IA analysis has been performed on the theoretical environmental discharges of a SRC-II facility located at Grayville, White County, Illinois. The results of this study, which show the SAM-IA forms properly filled out, are included in Appendix V.

In the SAM approach to environmental assessment, Level 1 is the initial waste stream analysis and is used to distinguish very hazardous waste streams from those which are less hazardous or are relatively innocuous. Level 1 data, consisting of identified organic classes of compounds and inorganic elements, generate the semiquantitative information which is then used to select the detailed and specific analyses required in Level 2.

SAMs can be used to do one or more of the following:

- Rank waste streams. In this application, the SAM is used to compare the toxic-unit rate of discharge of each waste stream; these toxic-unit summations can then be ranked by magnitude. Examination of the relative magnitudes generated by different streams immediately shows the relative hazard of the different waste streams. Unfortunately, this summation as yet does not indicate absolutely if the waste stream will be environmentally hazardous.

- Establish specific Level 2 and additional Level 3 sampling and analysis priorities in performing environmental assessments.

- Determine problem pollutants and pollutant priorities. In this application, use of the SAM can lead to an understanding of which pollutants are most likely to cause major environmental impact because they remain poorly controlled under all equipment options currently available.

- Determine which control technology options are the most effective. In this application, the SAM is used to examine a given process stream with first one and then another control approach. The impact of alternative control equipment choices can be compared on the basis of:

  - The differing reductions which can be expected to occur in the original process stream pollutants

  - The ways in which concentration of certain pollutants into particular control equipment waste streams will occur.

- Determine the need for control/disposal technology development.

A-I.2.2 SAM/IA Calculation Procedure

The steps included in the SAM/IA approach are as follows:

(1) Identify specific unit operations within the overall system or process.

(2) Identify the various waste streams from that unit operation. Each gas, liquid, or solid waste discharge is included as a separate waste stream.

(3) Determine the concentration of each sample fraction (Level 1) or specific pollutant species (Level 2) to be considered in each waste stream. In Level 1 assessments, the set of species potentially present which would lead to hazard is established at this point for each sample fraction.

(4) Each class of compounds or specific pollutant concentration in a given waste stream is then divided by its corresponding health-based MATE if this value is available. This quantity is,

henceforth, called a "degree of hazard". A second quotient is formed using the corresponding ecological MATE. For example, the concentration of phenol in the aqueous waste stream from the proposed SRC facility will average 0.4 mg/l (range 0-0.6 mg/l). The MATE based on health effects is 5.0 μg/l. Thus, the degree of hazard based on health effects is 400 ÷ 5 = 80 based on the average and 600 ÷ 5 = 120 based on the maximum. Obviously, a degree of hazard value greater than one indicates that the pollutant concentration in a particular waste stream is greater than the corresponding MATE and, therefore, probably will cause environmental problems. Thus, phenols in the aqueous waste stream may represent a significant environmental problem.

(5) At this point, each pollutant entry for which the health or ecological degree of hazard is greater than unity is flagged. These flags have been put on the form specifically for later ease in spotting potential problem pollutants.

(6) The final calculation for each pollutant species or small fraction in each stream takes the product of its degree of hazard and the waste stream flow rate to establish health (or ecological) toxic unit discharge rates (TUDR).

(7) The total stream degree of hazard is then calculated as the sum of the health or ecological degree of hazard for each pollutant. Further, the total stream TUDR is calculated by summing the individual pollutant entry toxic unit discharge rates.

(8) Degrees of Hazard and Toxic Unit Discharge Rates are then grouped and summed by gaseous, water, and solid waste streams.

(9) Finally, if a Level 1 assessment is being performed, any additional data which can be used to rule out the presence of a chemical species is noted.

It should be noted that the third step requires an enumeration of all of the components of a given effluent stream which are to be considered. If a component is not included in the enumeration, any environmental impact which results from its discharge will not be included in the results.

The SAM/IA format will ordinarily be used for rapid screening of the difference between an uncontrolled process and the results of the application of various control options. Thus, it will ordinarily be applied to confined or ducted sources.

APPENDIX II

MULTIMEDIA ENVIRONMENTAL GOALS FOR ASSESSMENT: DETAILED DISCUSSION

EXISTING ENVIRONMENTAL REQUIREMENTS

A-II MULTIMEDIA ENVIRONMENTAL GOALS FOR ASSESSMENT: DETAILED DISCUSSION AND EXISTING ENVIRONMENTAL REQUIREMENTS

A-II.1 Multimedia Environmental Goals for Assessment: Detailed Discussion

Figure A-II-1 is an example of a MEG chart. Emission Level Goals, which are listed in the top half of Figure A-II-1, are desirable levels of contaminants in point source or fugitive emissions. Discharge streams addressed by Emission Level Goals may be gaseous, aqueous, or solid in nature. Emission Level Goals for chemical contaminants may be described on the basis of technology factors or ambient factors. Technology-Based Emission Level Goals (Section I, top half of the figure) have not been addressed in the current MEGs.

Five specific criteria for Emission Level Goals based on ambient factors have been included in the MEG methodology. These are (1) Minimum Acute Toxicity Effluents (MATEs) (Column II-A, top half of Figure A-II-1) based on human health effects; (2) MATEs based on ecological effects; (3) Ambient Level Goals (Column II-B, top half of Figure A-II-1) based on human health effects; (4) Ambient Level Goals based on ecological effects; and (5) concentrations representing Elimination of Discharge (EOD).

The Ambient Level Goals found in Column II-B of the top half of Figure A-II-1 are simply transcriptions of the lowest current or proposed Ambient Standards or Criteria or Estimated Permissible Concentrations (EPCs) which are found in the lower half of the figure. These Current or Proposed Federal Ambient Standards or Criteria, or EPCs, are derived from literature values and are based both on health and

	EMISSION LEVEL GOALS						
	I. Based on Best Technology		II. Based on Ambient Factors				
	A. Existing Standards	B. Developing Technology	A. Minimum Acute Toxicity Effluent		B. Ambient Level Goal*		C. Elimination of Discharge
	NSPS, BPT, BAT	Engineering Estimates (R&D Goals)	Based on Health Effects	Based on Ecological Effects	Based on Health Effects	Based on Ecological Effects	Natural Background*
Air, µg/m³ (ppm Vol)			1.9E4 (5)		45 (0.01)		
Water, µg/l (ppm Wt)			5.0E0	5.0E2	1	100	
Land, µg/g (ppm Wt)			1.0E-2	1.0E0	0.002	0.2	

*To be multiplied by dilution factor

	AMBIENT LEVEL GOALS				
	I. Current or Proposed Ambient Standards or Criteria		II. Toxicity Based Estimated Permissible Concentration		III. Zero Threshold Pollutants Estimated Permissible Concentration
	A. Based on Health Effects	B. Based on Ecological Effects	A. Based on Health Effects	B. Based on Ecological Effects	Based on Health Effects
Air, µg/m³ (ppm Vol)			45 (0.01)		
Water, µg/l (ppm Wt)	1†	100†	260	500	
Land, µg/g (ppm Wt)			0.002	0.2	

†Phenolic compounds.

Figure A-II-1. MEG chart for phenol

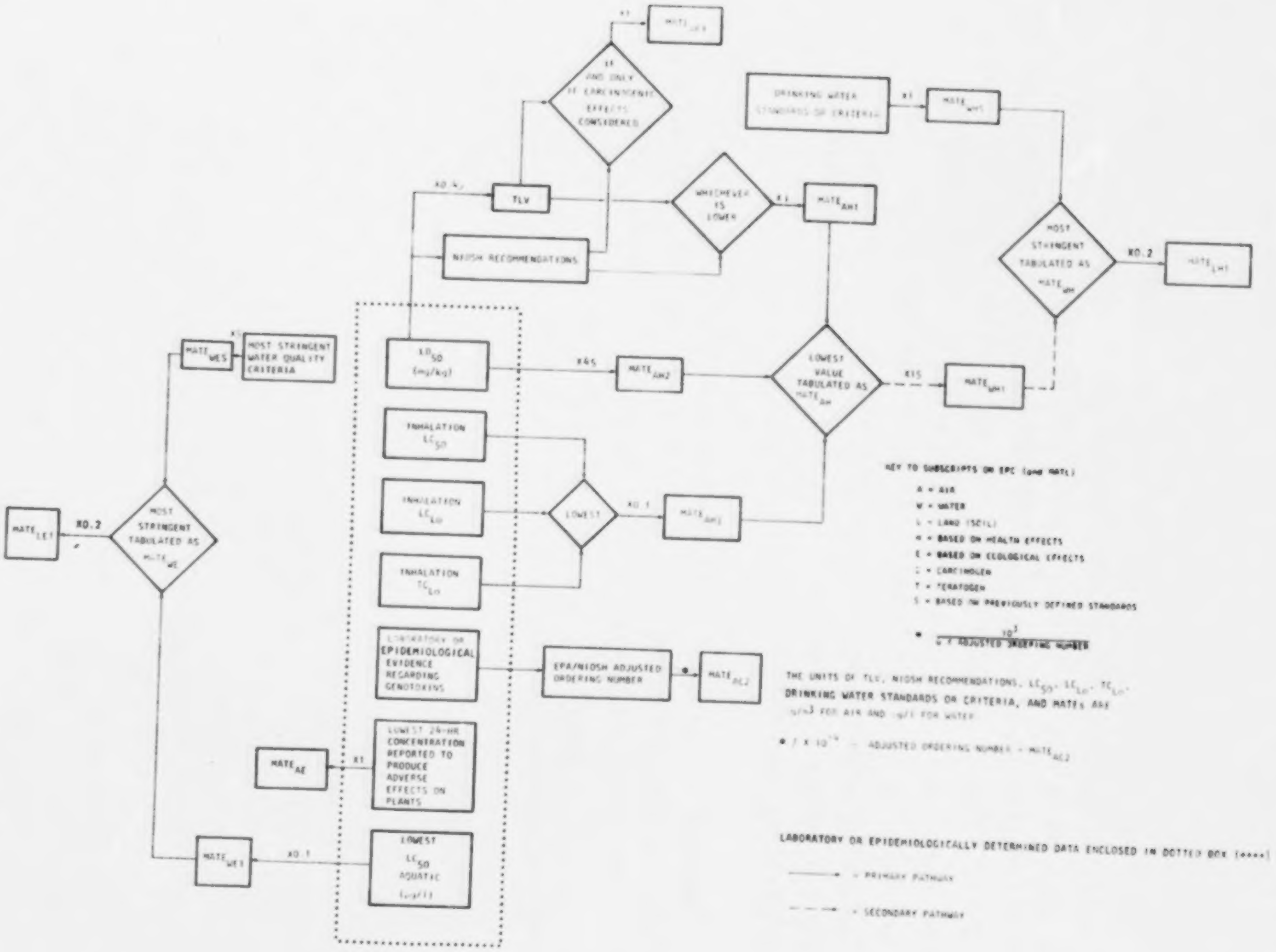
ecological effects. The specific mechanism for derivation of these MATEs and EPCs is given later in this appendix.

A-II.1.1 MEGs

MATE and EPC values that serve as Emission Level Goals are derived by multiplication factors which translate empirical data for each specific chemical substance into concentrations describing minimum acute toxicity concentrations. The rationale behind the numerical value of each of the factors is described in Reference 1. MATE and EPC values related to human health effects and those related to ecological effects are presented separately in the MEG chart, allowing a maximum of six MATE and 15 EPC values to be specified for each substance addressed.

Figures A-II-2 and A-II-3 show how the MATE and EPC values for the MEGs are derived. For either the MATE or EPC value the first subscript letter denotes the medium addressed (A = air, W = water, L = land). The second subscript letter indicates the application (H = human health effects, E = ecological effects, C = carcinogenicity, T = teratogenicity). The third subscript may be the letter "s," indicating that the EPC or MATE reflects current or proposed federal standard criteria or recommendation, or it may be a number indicating the particular model being applied. "Model numbers" are assigned in this subscript only when more than one conversion factor has been described to translate a particular data base. A fourth subscript, "a," indicates the EPC or MATE is expressed in parts per million.

In Figures A-II-2 and A-II-3 the conversion factors to convert from one data base to an EPC or MATE, or to interconvert from EPCs or MATEs, are given on the arrows. For


x1
MATE_LCT
IF AND ONLY IF CARCINOGENIC EFFECTS CONSIDERED
DRINKING WATER STANDARDS OR CRITERIA
x1
MATE_WH1
X0.4
TLV
WHICHEVER IS LOWER
x1
MATE_AH1
NIOSH RECOMMENDATIONS
MOST STRINGENT TABULATED AS MATE_WH
X0.2
MATE_LH1
x1
MATE_WES
MOST STRINGENT WATER QUALITY CRITERIA
LD50 (mg/kg)
x45
MATE_AH2
LOWEST VALUE TABULATED AS MATE_AH
x15
MATE_WH1
MATE_LE1
X0.2
MOST STRINGENT TABULATED AS MATE_WE
INHALATION LC50
INHALATION LCLo
LOWEST
X0.1
MATE_AH3
INHALATION TCLo
LABORATORY OR EPIDEMIOLOGICAL EVIDENCE REGARDING GENOTOXINS
EPA/NIOSH ADJUSTED ORDERING NUMBER
MATE_AC2
LOWEST 24-HR CONCENTRATION REPORTED TO PRODUCE ADVERSE EFFECTS ON PLANTS
x1
MATE_AE
LOWEST LC50 AQUATIC (µg/l)
X0.1
MATE_WE1

KEY TO SUBSCRIPTS ON EPC (and MATE)

A = AIR
W = WATER
L = LAND (SOIL)
H = BASED ON HEALTH EFFECTS
E = BASED ON ECOLOGICAL EFFECTS
C = CARCINOGEN
T = TERATOGEN
S = BASED ON PREVIOUSLY DEFINED STANDARDS

● $\frac{10^3}{6 \times \text{ADJUSTED ORDERING NUMBER}}$

THE UNITS OF TLV, NIOSH RECOMMENDATIONS, LC_{50}, LC_{Lo}, TC_{Lo}, DRINKING WATER STANDARDS OR CRITERIA, AND MATEs ARE µg/m³ FOR AIR AND µg/l FOR WATER

● 7 × 10⁻⁴ ÷ ADJUSTED ORDERING NUMBER = $MATE_{AC2}$

LABORATORY OR EPIDEMIOLOGICALLY DETERMINED DATA ENCLOSED IN DOTTED BOX (••••)

——→ = PRIMARY PATHWAY

– – –→ = SECONDARY PATHWAY

Figure A-II-2. Derivation of MATEs

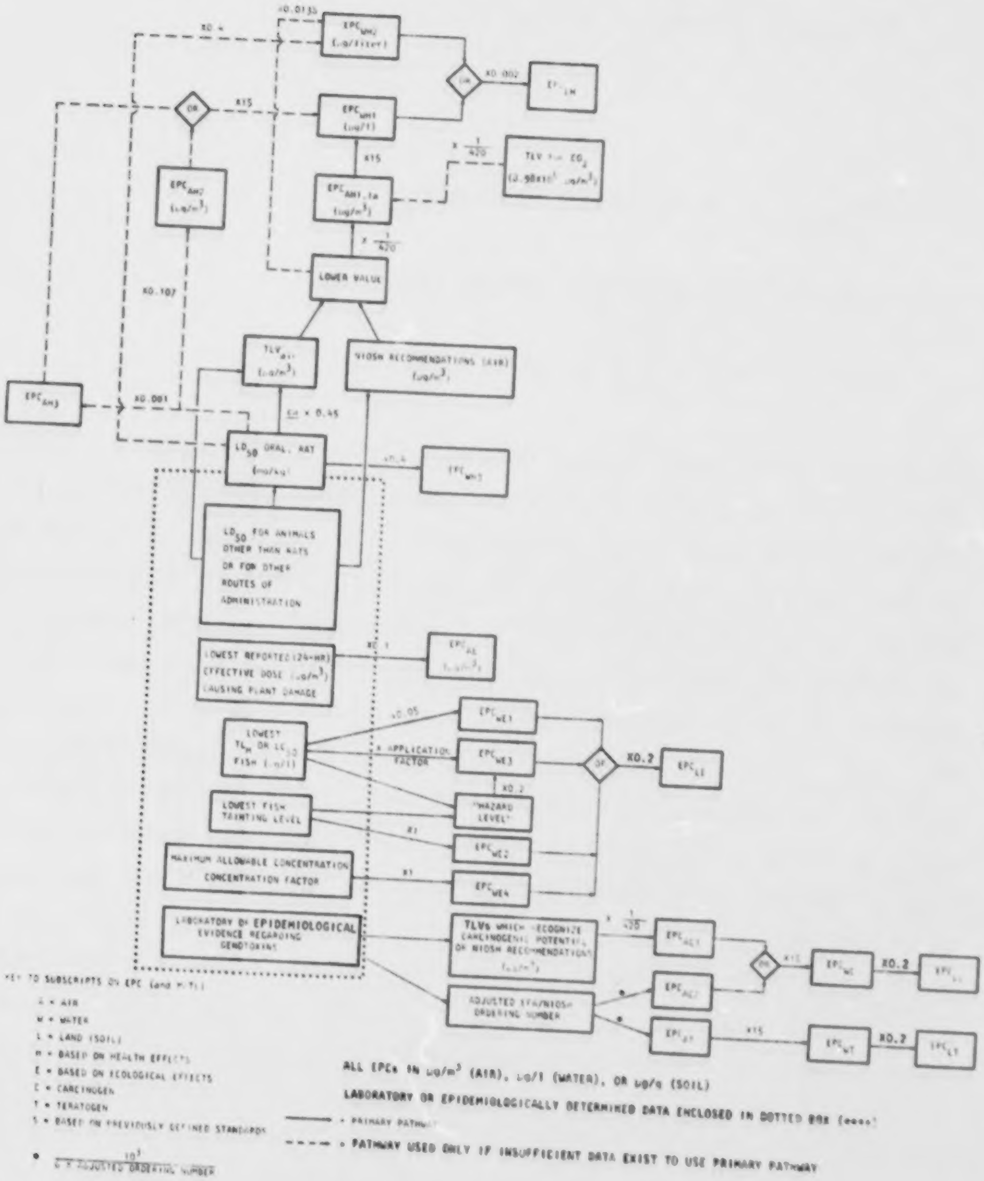

X0.0135
X0.4
EPC WH2 (µg/liter)
OR
X0.002
EPC LH
X15
EPC WH1 (µg/l)
X15
x 1/420
TLV for CO2 (2.98x10^5 µg/m^3)
EPC AH2 (µg/m^3)
EPC AH1,1a (µg/m^3)
x 1/420
LOWER VALUE
X0.107
TLV air (µg/m^3)
NIOSH RECOMMENDATIONS (AIR) (µg/m^3)
EPC AH3
X0.001
x 0.45
LD50 ORAL, RAT (mg/kg)
X0.4
EPC WH3
LD50 FOR ANIMALS OTHER THAN RATS OR FOR OTHER ROUTES OF ADMINISTRATION
LOWEST REPORTED (24-HR) EFFECTIVE DOSE (µg/m^3) CAUSING PLANT DAMAGE
X0.1
EPC AE (µg/m^3)
LOWEST TLm OR LC50 FISH (µg/l)
X0.05
EPC WE1
X APPLICATION FACTOR
EPC WE3
X0.2
"HAZARD LEVEL"
OR
X0.2
EPC LE
LOWEST FISH TAINTING LEVEL
X1
EPC WE2
MAXIMUM ALLOWABLE CONCENTRATION CONCENTRATION FACTOR
X1
EPC WE4
LABORATORY OR EPIDEMIOLOGICAL EVIDENCE REGARDING GENOTOXINS
TLVs WHICH RECOGNIZE CARCINOGENIC POTENTIAL OR NIOSH RECOMMENDATIONS (µg/m^3)
x 1/420
EPC AC1
OR
X15
EPC WC
X0.2
EPC LC
ADJUSTED STA/NIOSH ORDERING NUMBER
EPC AC2
EPC AT
X15
EPC WT
X0.2
EPC LT
KEY TO SUBSCRIPTS ON EPC (and MATE)
A = AIR
W = WATER
L = LAND (SOIL)
H = BASED ON HEALTH EFFECTS
E = BASED ON ECOLOGICAL EFFECTS
C = CARCINOGEN
T = TERATOGEN
S = BASED ON PREVIOUSLY DEFINED STANDARDS
● = 10^3 / 6 X ADJUSTED ORDERING NUMBER
ALL EPCs IN µg/m^3 (AIR), µg/l (WATER), OR µg/g (SOIL)
LABORATORY OR EPIDEMIOLOGICALLY DETERMINED DATA ENCLOSED IN DOTTED BOX (....)
= PRIMARY PATHWAY
= PATHWAY USED ONLY IF INSUFFICIENT DATA EXIST TO USE PRIMARY PATHWAY

Figure A-II-3. Derivation of EPCs

example, the TLV for ammonia is 18 mg/m^3 (25 ppm) or 18,000 $\mu g/m^3$. The corresponding air EPC based on health effects based on this TLV is:

$$EPC_{AH1} = \frac{18,000}{420} = 43\ \mu g/m^3$$

or

$$EPC_{AH1a} = 0.06 \text{ ppm (from } EPC_{AH1}).$$

The land EPC for ammonia would then be:

$$EPC_{LH} = 0.2 \times 43 \text{ or } 8.6\ \mu g/g$$

EPCs and MATEs are given in units of $\mu g/m^3$ for air, $\mu g/l$ for water, and $\mu g/g$ for soil when using the factors shown on the arrows in Figures A-II-2 and A-II-3. In order for the units to be correct when using the factors shown in Figures A-II-2 and A-II-3, the TLV or NIOSH recommendation and lowest effective atmospheric dose causing plant damage must be expressed in micrograms per cubic meter ($\mu g/m^3$). The LC_{50}, TL_m, LC_{Lo}, or TC_{Lo} must be expressed in micrograms per liter ($\mu g/l$) for water, or micrograms per cubic meter ($\mu g/m^3$) for air, and the LD_{50} in micrograms toxicant per gram animal ($\mu g/g$) which is equivalent to milligrams toxicant per kilogram animal (mg/kg). The lowest fish-tainting level is the concentration in the water where the fish was caught, expressed in micrograms per liter ($\mu g/l$). The lines connecting TLVs and NIOSH recommendations to experimental data are presented to indicate data on which these values are based. The air EPCs based on health effects are the Threshold Limit Values (TLVs) established by the American Conference of Governmental Industrial Hygienists (ACGIH) or the NIOSH Recommendations, whichever is lower, divided by 420. The air MATE based on health effects is simply the lower of the TLV or NIOSH recommendation when either of these two values is available. The TLVs represent time-weighted safe exposures based on 8 hours per day or 40 hours per week exposure for working adults. The NIOSH recommendations are thought to be maximum concentrations for the workroom atmosphere. In the absence of an applicable TLV or NIOSH recommendation, the values may be based on oral LD_{50} for the rat.

It is understandable that some readers may question the reliance on TLVs in the methodology developed for describing MEGs. The TLVs were established by the ACGIH as guidelines for prevention of adverse occupational exposures. The TLVs and the NIOSH recommendations are based on both animal studies and epidemiological findings and inferences representing the opinions of experienced physicians, toxicologists, and industrial hygienists. Their judgments regarding safe levels for workroom contamination, however, are not infallible. The ACGIH has made clear its intention that the TLVs are to be used solely in the practice of industrial hygiene; it does not recommend their use as a relative hazard index or in continuous exposure applications. However, because the TLVs (1) comprise the most comprehensive body of recommendations currently available regarding levels of human exposure to chemical contaminants, and (2) are widely accepted as valid indicators of permissible levels for occupational exposure in the continuing absence of data more reliable than the TLVs, their use in the MEG methodology, balanced as it is by consideration of such a wide array of other factors, is justified.

The use of mathematical formulas for translating animal toxicity data into EPCs or MATEs requires that certain assumptions be made. A worst-case approach has been taken to keep the MEG values conservative. Generally, MEGs derived from models which use LD_{50} or other acute toxicity animal data are more conservative than MEGs based on TLVs or NIOSH recommendations. In addition to the assumptions required for translating animal data to human health effects, arbitrary constants are employed in several cases as safety factors.

The types of experimental data to which these multiplication factors apply are as follows:

LD_{50} -- Dosage resulting in death (lethal dose) for 50 percent of the animal population tested

LD_{Lo} -- Lowest lethal dose reported for a species/route combination

LC_{50} -- Lethal concentration to 50 percent of the animals tested

TD_{Lo} -- Lowest toxic dosage reported to result in a specified response (for example, a carcinogenic response)

TL_m -- Threshold limit median, i.e., concentration to which 50 percent of aquatic population exposed exhibited the specified response

LC_{Lo} -- Lowest lethal concentration reported

TC_{Lo} -- Lowest toxic concentration reported to result in a specified response.

In derivation of the MEGs, the preferred LD_{50} is for oral administration of the compound to a rat. When this parameter has not been measured, the most closely related

LD_{50} or LD_{Lo} is used; a subjective decision as to which is the most closely related LD_{50} or LD_{Lo} is required.

The water EPC value derived from information in the Water Quality Criteria document is calculated by use of one of the following formulas:

$EPC_{WE3}(\mu g/l)$ = Application factor x lowest TL_m ($\mu g/l$), where the application factor is specified in recognized criteria

$EPC_{WE3}(\mu g/l)$ = Hazard level ($\mu g/l$) x 0.2, where hazard level is specified in recognized criteria.

The ecological EPC for water, based on cumulative factors (EPC_{WE4}), incorporates the reported concentration factor for a given chemical substance and the maximum allowable concentration of that contaminant in fish flesh. The following formula is used:

$$EPC_{WE4} = \frac{\text{maximum allowable concentration } (\mu g/kg)}{\text{concentration factor}}$$

Estimation of the EPCs and MATEs for "zero threshold pollutants" is difficult. Zero threshold pollutants are defined as substances that affect genes such as carcinogens, mutagens, and some teratogens (collectively called genotoxins). There may be no concentration of these compounds for which a no-effect response exists. In other words, a "single hit" by a single molecule of one of these compounds at a single specific cellular site may result in carcinogenesis, mutagenesis, or teratogenesis. An acceptable level for one of these compounds is usually considered to be one such that the chance of a specific hit is so low that the incidence of carcinogenesis, teratogenesis, or mutagenesis will not be significantly increased (at the 95 percent level) over the situation in which the compound is not present. In other words, at the 95 percent level of statistical significance, the rate of carcinogenesis, mutagenesis, or teratogenesis would quite probably be less than or equal to 1.05 times the rate when no genotoxin is present. The chance of a "single hit" at a specific site by any one particular chemical is dependent on the availability of the site to that chemical, and the reactivity of that chemical at the site. The factors influencing the availability of the site to the chemical range from stereochemical considerations of the site and the chemical, to the route and efficiency of absorption of the chemical into the organism. The routes and efficiencies of absorption of chemicals are dependent on the form and availability of the chemical to the organism, and the general health and nutritional status of the organism. Thus, the potency of chemical genotoxins differs greatly. Unfortunately, the LD_{50} values and other acute toxic parameters discussed previously give no indication of the carcinogenic, mutagenic, or teratogenic effects of a compound. The EPC for genotoxins must therefore be based on parameters which are different from the toxicological parameters discussed previously.

The EPC_{AC2} is derived from a model which translates adjusted ordering numbers, based on a ranking system for suspected carcinogens, into permissible air concentrations. The system for establishing adjusted ordering numbers is a refinement of an ordering plan developed by the EPA Office of Toxic Substances, and reported in An Ordering of the NIOSH Suspected Carcinogens List Based on Data Contained in the List (1). EPA's ordering plan resulted in the assignment of four-digit ordering numbers (hereafter referred to as EPA-NIOSH ordering numbers) for all those substances entered in the NIOSH Suspected Carcinogens List. The numbers assigned to the EPA plan are an "indication of the relative degree of concern that might be warranted for a particular substance regarding its possible carcinogenic potential." It is not appropriate, however, to conclude that all the substances which are assigned a number are carcinogenic.

The derivation of EPA-NIOSH ordering numbers follows:

- First digit -- the number corresponding to the highest-priority species giving a response is assigned as the first digit of the ordering number. Priorities are delineated below:

Species (in order of priority)	Number
Human	7
Monkey	6
Cat, dog, pig, cattle, or other domestic animal	5
Rat	4
Mouse	3
Guinea pig, gerbil, hamster, rabbit, squirrel, or unspecified mammal	2
Bird	1
Frog	0

- Second digit -- the number of different species reported to have developed tumors as a result of exposure determines the second digit of the ordering number. (The highest number that can be entered is 9).

- Third digit -- the third digit is designated 0, 1, or 2, according to the most significant route of administration eliciting an oncogenic response.

Various routes of administration and the corresponding digit assignment are:

Inhalation, ocular, or skin application	2
Oral administration	1
All other routes	0

The highest number applicable is assigned.

- Fourth digit -- the total number of species/route combinations reported is entered as the fourth digit of the ordering number. (The highest number that can be entered is 9).

As an example, the first digit of the EPA-NIOSH ordering number for dibenz(a,h)anthracene will be 4, since the rat is the highest priority species in which a carcinogenic response is reported. Oncogenicity has been demonstrated in five different species. Thus, the second digit of the ordering number is 5. The third digit is 2, since the data indicate that one route of administration affecting an oncogenic response is skin application. Since 9 species/route combinations are reported, the fourth digit of the ordering number is 9. The complete four-digit EPA-NIOSH ordering number therefore is 4529.

The EPA-NIOSH ordering numbers have been modified in the MEG methodology to incorporate effective dosages indicating carcinogenic potential of chemical substances. As described above, the EPA-NIOSH ordering number successfully incorporates information related to animals and routes of administration with arbitrary, but carefully considered, weighting given to each item. However, no consideration has been given in such ordering numbers to effective dosages required. By incorporating lowest effective dosages, the reliability of the system for ranking suspected carcinogens is strengthened.

EPA-NIOSH ordering numbers have been modified to dosage-adjusted ordering numbers, hereafter referred to as adjusted ordering numbers. The following equation describes the modified ordering numbers:

$$\text{Adjusted ordering number} = \frac{\text{EPA-NIOSH ordering number}}{\text{Lowest dosage resulting in an oncogenic response (mg/kg)}}$$

Adjusted ordering numbers determined for various substances usually range from less than 0.1 to greater than 3,000,000. Very large adjusted ordering numbers indicate that a small dosage was required to affect the response. On the other hand, a small number indicates a high dosage was required. Thus, adjusted ordering numbers increase with the expected potency of a chemical carcinogen. Substances with adjusted ordering numbers lower than one are generally not treated as suspected carcinogens in the calculation of the EPCs as part of the MEG methodology.

The adjusted ordering numbers just described provide an effective system for ranking genotoxins. Furthermore, it may be assumed that EPCs for suspected carcinogens and teratogens will be inversely proportional to such ordering numbers:

$$\text{EPC}_{\text{carcinogen}} = \frac{K}{\text{adjusted ordering number}}$$

K (for model EPC_{AC2}) is arbitrarily assigned a value of 1/6 in order to establish EPCs lower than 1 nanogram for the most potent carcinogens:

$$EPC_{AC2}(\mu g/m^3) = \frac{10^3}{6 \times \text{adjusted ordering number}}$$

The adjusted ordering numbers for several compounds are given in Table A-II-1.

TABLE A-II-1. ADJUSTED ORDERING NUMBERS FOR SEVERAL INORGANICS AND ORGANICS

Substance	Adjusted ordering no.
Beryllium	16,000,000
Benzo(a)pyrene	3,314,500
Dibenz(a,h)anthracene	754,833
7,12-Dimethylbenz(a)anthracene	272,809
N-Nitrosodimethylamine	59,053
3-Methylcholanthrene	18,683
Cadmium	7,329
Chromium	7,327
Selenium	6,426
N,N'Dimethylhydrazine	2,208
Cobalt	1,682
Dibenz(a,i)pyrene	1,612
Benz(a)anthracene	1,562
Dibenz(c,g)carbazole	679
Aminotoluenes	638
N-Nitrosodiethylamine	577
Nickel	477
2-Aminonaphthalene	423
Dibenz(a,h)acridine	312.4
Dibenz(a,j)acridine	284
Ethylenimine	210.6
Lead	136
1-Aminonaphthalene	124
Diazomethane	78
Benzo(b)fluoranthene	78
Dibenzo(a,l)pyrene	64.6
4-Aminobiphenyl	54
4-Nitrobiphenyl	54
Phenanthrene	44
Indeno(1,2,3-cd)pyrene	43
Formaldehyde	42.7
Methyl chrysenes	39
Tetraethyl lead	36
p-Dimethylaminoazobenzene	35
Chrysene	31.5
Picene	28
Nickel carbonyl	26

(continued)

TABLE A-II-1. (continued)

Substance	Adjusted ordering no.
Benzo(e)pyrene	23
Nickelocene	20.2
Copper 8-hydroxyquinoline	20
Dibenzo(a,h)pyrene	18.9
Dibenzo(a,g)carbazole	11.6
Benzo(j)fluoranthene	10.8
Hydrazine	10.6
Mercury	10.5
2,4-Dichlorophenol	10
Dibenz(a,c)anthracene	7.1
Benz(c)acridine	6.67
Indole	6.5
Dibenz(a,i)carbazole	6
1-Chloro-2,3-epoxypropane	4.3
Phthalate esters	4.3
Benzo(g)chrysene	4.3
Benzidine	3.5
Dibenz(c,h)acridine	3.06
Benzo(c)phenanthrene	2.5
α-Chlorotoluene	1.9
Silver	1.7
Anthracene	1.3
Naphthalene	1.2
Monomethylhydrazine	1
Pyrene	0.3

The air EPC for a teratogen (EPC_{AT}), is calculated in a manner exactly analogous to the method used to calculate the air EPC for a carcinogen. The EPCs for carcinogenic (EPC_{WC}) and teratogenic (EPC_{WT}) substances in water are derived from the EPCs for air for a given substance as shown in Figure A-II-2. The land EPCs for genotoxins are based on their respective water EPCs.

A-II.1.2 Apparent Reliability of MATE, EPA, and EOD Values

Figures A-II-2 and A-II-3 give the impression that the MATEs and EPCs are based on very little actual data. In reality, very little data exist, except as listed in these figures, which can be applied to the environment. This state of affairs arises from the fact that meaningful experiments are difficult to conceive, expensive to carry out and are time consuming.

The MEG methodology does not consider synergistic and antagonistic effects. Tables A-II-2 and A-II-3 list some of these effects. The biological interrelationships between elements are so complex that all possible effects of this type cannot be studied.

A-II.1.3 Background Information Summaries for the MEGs

The MEG background information summary gives the IUPAC name of the material, the empirical chemical formula, major synonyms, a description of the physical properties, the Wiswesser Line-Formula notation, and a visual structural diagram. The Wiswesser Line-Formula Notation gives a unique unambiguous topological description of the structure of each substance. The natural occurrence, characteristics, and associated compounds are also catalogued in the background information summary. The reported toxic properties and health effects, including the NIOSH ordering numbers for carcinogens, are given. The potential for bioaccumulation is given, as well as regulatory actions, standards, criteria, recognition, candidate status for specific recognition, MATEs and EPCs.

The LD_{50} and LC_{50} values are given in the background information summary. When the LD_{50} is not available, the lowest published lethal dose (LD_{Lo}) is given. When the LC_{50} is not available, the lowest published lethal concentration (LC_{Lo}) is given.

TABLE A-II-2. REDUCTION OF THE TOXIC EFFECTS OF ONE COMPOUND BY ANOTHER COMPOUND

Compound	Organism	Effect
Arsenic		Selenium is carcinogenic and teratogenic, but is antagonistic to the carcinogenic and teratogenic effects of arsenic.[a]
Beryllium	Aquatic organisms	Increasing the pH reduces the toxic effects of beryllium,[b,c] as does increasing the water hardness.[b,d-k]
Cadmium	Humans	Selenite is reported to protect reproductive tissues and mammary glands against the hemorrhagic necrosis produced by cadmium, and may also protect against cadmium-induced hypertension.[l]
	Algae	The magnitude of cadmium-induced photosynthesis decrease is reduced by ethylene diamine diacetic acid.[m]
	Algae	Zinc, cobalt, and selenium are antagonistic to cadmium and may act to reduce the response it evokes.[b]
	Rat	The occurrence of rat intestinal cell tumors induced by injection of 0.03 mmole cadmium chloride/kg was reduced or eliminated by simultaneous injection of 3.0 mmole zinc acetate.[h]
	Aquatic organisms	Increasing the water hardness decreases the toxicity of cadmium,[b,d-l,o,p-t], as does increasing salinity,[b,d-k] increasing pH[b,c] and increasing dissolved oxygen[b,d-k,q-t].
	Hamsters	Sodium selenate reduces teratogenicity of injected cadmium if injected within 1/2 hour (both compounds at 2 mg/kg in mother - sodium selenate not teratogenic at this concentration)[a].
Calcium	Oats	Both root and shoot weights were restored when the plants were exposed to nickel in the presence of calcium.[a]
Cobalt	Aquatic organisms	Increasing the water hardness decreases the toxicity of cobalt as does increasing dissolved oxygen.[b,d-k,q-t]

(continued)

TABLE A-II-2. (continued)

Compound	Organism	Effect
Copper	Algae	Ethylenediaminetetracetic acid reduces algicidal effects of copper on an equivalent basis.[a]
		Molybdenum is antagonistic to toxic effects of copper.[a]
	Aquatic organisms	Increasing the water hardness decreases the toxicity of copper.[b,d-l,o,p-t]
Iron	Aquatic organisms	Increasing the pH decreases the uptake of iron.[b,c]
Lead		Phenobarbital may be beneficial in coping with the deleterious effects of lead intoxication.[u]
	Aquatic organisms	Increasing the water hardness decreases the toxicity of lead,[b,d-l,o,p-t] as do increasing dissolved oxygen,[b,d-k,q-t] and increasing pH.[b,c]
	Chicks	Selenium to 5 ppm in diet has mildly protective action against toxic effects of lead.[a]
Magnesium	Oats	Both root and shoot weights were restored when the plants were exposed to nickel in the presence of magnesium.[a]
Manganese	Aquatic organisms	Increasing the pH decreases the uptake of manganese.[b,c]
Mercury	Humans	Alcohol consumption was shown to reduce mercury absorption in the blood.[u]
	Rats	Assimilation of arsenic affords partial protection against mercury.[l]
	Algae, rats plants	Selenium compounds have a protective effect against the toxic action of mercury compounds.[a,b]
	Aquatic organisms	Increasing dissolved oxygen decreases the toxicity of mercury,[b,d-k,q-t] as do increasing salinity[b,d-k] and increasing pH.[b,c]

(continued)

TABLE A-II-2. (continued)

Compound	Organism	Effect
Molybdenum	Aquatic organisms	Increasing the pH decreases the uptake of molybdenum.[c]
Nickel	Microbe	Magnesium restored nickel-inhibited acid production and glucose utilization.[a]
	Plants	Sufficient iron reduces the phytotoxicity of nickel.[a]
	Freshwater algae	Toxicity of nickel is eliminated by Na_2 EDTA and reduced by zinc.[a]
Selenium	Chicks and rats	Arsenic salts have been shown to counteract adverse selenium effects.[l]
	Rats	Linseed oil offers protection against liver damage from selenium.[l]
	Aquatic organisms	Increasing the pOH decreases the uptake of selenium.[c]
	Freshwater algae	Algae grown in media containing sulfur were less prone to the toxic effects of selenium.[a]
	Chicks	Addition of dietary copper or silver (1,000 ppm) counteracted the toxic effects of 40 ppm dietary selenium.[a]
Silver	Green algae, fungi, bacteria	The algae could compete with chloride for silver ion (thereby exerting an algistatic or algicidal effect), but bromine ions partially reduced the toxicity of a given level of silver to the algae and iodide caused a drastic reduction.[v]
Thallium	Rats	Selenium gives some protection against liver damage by thallium.[l]
Vanadium	Chicks	Chromium was found to give considerable protection against vanadium.[l]
Zinc	Aquatic organisms	Increasing the pH reduces the toxic effects of zinc,[b,o-i,w] as do increasing the water hardness[b,d-lo,p-t] increasing the dissolved oxygen[b,d-k,q-t] and increasing salinity.[b,d-k]

(continued)

Footnotes to Table A-II-2

[a] Hittman Associates. Environmental Assessment of Effluents from Coal Liquefaction, Contract No. 68-02-2162/Task Directive 4, U.S. Environmental Protection Agency, Industrial and Environmental Research Laboratory, Research Triangle Park, North Carolina, 1977.

[b] Wilkes, D.J. Chapter 9: Animals: Bioenvironmental Effects. In: Environmental, Health, and Control Aspects of Coal Conversion: An Information Overview, Vol. 2, H.M. Braunstein, E.D. Copenhaver, and H.A. Pfuder, eds. Information Center Complex, Information Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37830, 1977.

[c] Carrier, R.F. Chapter 8: Plant Interactions. In: Environmental, Health, and Control Aspects of Coal Conversion: An Information Overview. Vol. 2, H.M. Braunstein, E.D. Copenhaver, and H.A. Pfuder, eds. Information Center Complex, Information Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37830, 1977.

[d] Lisk, D.J. Trace Metals in Soils, Plants, and Animals. In: Advances in Agronomy, Vol. 24, N.C. Brady, ed. Academic Press, New York, 1972. pp. 267-325.

[e] Lloyd, R. The Toxicity of Zinc Sulphate to Rainbow Trout. Ann. Appl. Biol., 48(1):84-94, 1960.

[f] Cairns, J., Jr., et al. The Effect of pH, Solubility, and Temperature upon the Acute Toxicity of Zinc to the Bluegill Sunfish (Lepomis macrochirus Raf.). Trans. Kansas Acad. Sci., 74(1):81-92, 1971.

[g] Jones, M.B. Synergistic Effects of Salinity, Temperature and Heavy Metals on Mortality and Osmoregulation in Marine and Estuarine Isopods (Crustacea). Mar. Biol., 30(1):13-20, 1975.

[h] Negilski, D.S. Acute Toxicity of Zinc, Cadmium, and Chromium to the Marine Fishes, Yellow-Eye Mullet (Aldrichetta forsteri C. & V.) and Small-Mouthed Hardyhead (Atherinasoma microstoma Whitley). Aust. J. Mar. Freshwater Res., 27(1):137-49, 1976.

[i] Elson, P.F., et al. Impact of Chemical Pollution on Atlantic Salmon in North America. The International Atlantic Salmon Foundation. In: International Atlantic Symposium 1973, pp. 83-110, 1973.

[j] Kinkade, M., and M. Erdman. Influence of Hardness Components in Water on the Uptake and Concentration of Cadmium in a Simulated Freshwater Environment. Environmental Research, 10(2):308-313, 1975.

[k] Pickering, A.H. and C. Henderson. Acute Toxicity of Some Heavy Metals to Different Species of Freshwater Fish. In: Proceedings of the 19th Industrial Waste Conference, Purdue University. Lafayette, Indiana. 35:578-91, 1965.

(continued)

Footnotes to Table A-II-2 (continued)

[l] Jenne, E.A. and S.N. Louma. Forms of Trace Elements in Soils, Sediments, and Associated Waters: An Overview of Their Determination and Biological Availability. In: Biological Implications of Metals in the Environment. Proceedings of the Fifteenth Annual Hanford Life Sciences Symposium at Richland, Washington, H. Drucker and R.E. Wildung, eds. Sponsored by Battelle, Pacific Northwest Laboratories and Division of Biomedical and Environmental Research, Energy Research and Development Administration, Washington, D.C., and September 29 - October 1, 1975, 1977.

[m] Sarsfield, L.J. and K.H. Mancy. The Properties of Cadmium Complexes and Their Effect on Toxicity to a Biological System. In: Biological Implications of Metals in the Environment, H. Drucker and R.E. Wildung, eds. Proceedings of the Fifteenth Annual Hanford Life Sciences Symposium at Richland, Washington, Sponsored by Battelle, Pacific Northwest Laboratories and Division of Environmental Research, Energy Research and Development Administration, Washington, D.C., September 29 - October 1, 1975, 1977.

[n] Gunn, S.A., T.C. Gould and W.A.D. Anderson. Cadmium-Induced Interstitial Cell Tumors in Rats and Mice and Their Prevention by Zinc. J. Nat. Center Inst., 31:745-753, 1963.

[o] Slonium, A.R. 1973. Acute Toxicity of Beryllium Sulfate to the Common Guppy. J. Water Pollut. Control Fed., 45(10):2110-2122, 1973.

[p] Christensen, G.M., et al. Changes in the Blood of the Brown Bullhead (Ictalurus nebulosus (Lesueur)) Following Short and Long Exposure to Copper (II). Toxicol. Appl. Pharmacol., 23:417-427, 1972.

[q] Pickering, Q.H. Acute Toxicity of Some Heavy Metals to Different Species of Warm Water Fishes. Air Wat. Int. J., 10:453-463, 1966.

[r] Dilling, W.J., C.W. Healey and W.C. Smith. Experiments on the Effects of Lead on the Growth of Plaice (Pleuronectes platessa). Ann. Appl. Biol., 13:168-176, 1926.

[s] Biesinger, K.E. and G.M. Christensen. Effect of Various Metals on Survival, Growth, Reproduction, and Metabolism of Daphnia magna. J. Fish. Res. Board Can., 29(12):1691-1700, 1972.

[t] Lloyd, R. Effects of Dissolved Oxygen Concentrations on the Toxicity of Several Poisons to Rainbow Trout (Salmo gairdnerii Richardson). J. Exp. Biol., 38:447-455, 1961.

[u] Environmental Health Resources Center. Health Effects and Recommendations for Atmospheric Lead, Calcium, Mercury and Asbestos. Report No. IIEQ 73-2 (PB 220224), Illinois Institute for Environmental Quality, 309 West Washington Street, Chicago, Illinois 60606, 1973. 101 pp.

[v] Fitzgerald, G.P. The Algistatic Properties of Silver. Water and Sewage Works, 114:185-189, 1967.

[w] Bowen, H.J.M. Trace Elements in Biochemistry. Academic Press, New York, 1966.

TABLE A-II-3. INCREASE IN TOXIC EFFECTS OF ONE COMPOUND BY ANOTHER COMPOUND

Compounds	Organism	Effect
Cadmium copper zinc	Fathead minnow	A lethal threshold was reached when each metal in the mixture was present at a concentration of 40 percent or less or its individual lethal threshold. Spawning and hatching success has also been shown to be impaired to a greater degree under exposure to several metals than to each metal singly.[a]
Cadmium lead	Corn	Corn root elongation was inhibited by combinations of noninhibitory concentrations of cadmium (2-100 micrograms/gram of soil) and lead (100-200 micrograms/gram of soil).[b,c]
Cadmium zinc	Floating aquatic plants	Cadmium and zinc have been found to act synergistically in inhibiting the growth of floating aquatic plants. Although zinc alone was stimulatory, it markedly increased the inhibitory effect of cadmium. The presence of one also increased uptake of the other, which may account for their synergistic toxic action.[d]
	Spinach	Cadmium and zinc showed synergistic toxicity on photosynthesis by isolated spinach chloroplasts.[e]
Copper cadmium	Copepod	Growth and development was inhibited to a greater degree by exposure to combinations of copper and cadmium than to either metal ion alone.[a]
Copper iron	Citrus plants	Chlorosis has resulted from an imbalance between soil copper and iron caused by accumulated copper from fertilizers and fungicidal sprays.[d]
Copper mercury	Freshwater crayfish	The effect of copper (II) and mercury (II) is synergistic.[f]

(continued)

TABLE A-II-3. (continued)

Compounds	Organism	Effect
Copper mercury detergents	Rainbow trout	The toxicity to rainbow trout of copper, mercury, and three detergents (two anionics and one nonionic) was determined in 14-day exposures. For mixtures of anionic detergents and metals, a more-than-additive effect existed, whereas for the mixture of nonionic detergent and metal, the toxic effect was less than additive.[a]
Copper nickel pH	Algae	The synergistic toxic relationship between copper and nickel is enhanced by low pH levels.[d]
Copper silver	Filamentous green algae	This algae showed an LC_{50} of 200 ppb for silver alone or an LC_{50} of 50 ppb for silver in the presence of copper. The LC_{50} of this organism for copper alone was 600 ppb.[g]
Copper zinc	Rainbow trout	Combined concentrations of 0.04 ppm copper and 0.66 ppm zinc show a 50 percent increase in coughing frequency in fish over the sum of the responses to 0.04 ppm copper and 0.66 ppm zinc administered alone. A loss of skin pigment and excess mucus on the body surface was also noted in the copper zinc exposures of high concentration, whereas copper alone never caused excess mucus or loss of color.[b]
	Rainbow trout	Short-term (seven days) experiments on rainrow trout showed that synergistic effects occurred in soft water when the copper concentration exceeded 0.3 ppm and the zinc concentration exceeded 1.8 ppm, while in hard water the effects of copper and zinc were additive at all concentrations.[g]
Cyanide iron	Wheat	The normal inhibition of wheat leaf elongation by cyanide was increased considerably at between 0.5 to 1.0 mM cyanide when iron was present in the nutrient solution.[d]

(continued)

TABLE A-II-3. (continued)

Compounds	Organism	Effect
Lead acetate zinc oxide	Yorkshire pigs	Dietary zinc oxide (4,000 ppm) aggregates dietary lead acetate (1,000 ppm).[g]
Manganese iron copper	Plants	Plant deficiency of manganese can occur if amounts of available iron and/or copper are excessive.[d]
Mercury lead zinc	Marine ciliate	The growth rate was inhibited to a greater degree (67.2% reduction) by a combination of mercury (0.005 ppm as $HgCl_2$), lead [0.3 ppm as $Pb(No_3)_2$], and zinc (0.25 ppm as $ZnSO_4$) than for any one, or combination of two, of these metals. Singly, mercury reduced growth rate by 12%, lead by 11%, and zinc by 13%.[h]
Mercury selenium	Carp	A greater effect on hatchability of carp eggs was observed when the eggs were exposed to mixtures of mercury and selenium than when the eggs were exposed to these agents singly.[a]
Mutagenic ions individual metals radiation	Plants	Additive effects have been observed when combinations of mutagenic ions and/or individual metals were applied with radiation.[d]
Nickel manganese		Nickel toxicity may increase when there is an abundance of manganese present.[i]

[a] Wilkes, D.J. Chapter 9: Animals, Bioenvironmental Effects. In: Environmental, Health, and Control Aspects of Coal Conversion: An Information Overview, Vol. 2, H.M. Braunstein, E.D. Copenhaver, and H.A. Pfuder, eds. Information Center Complex, Information Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37830, 1977.

[b] Folmar, L.C. Overt Avoidance Reaction of Rainbow Trout Fry to Nine Herbicides. Bull. Environ. Contam. Toxicol., 15(5):509, 1976.

[c] Bazzaz, M.B. and Govindjee. Effects of Lead Chloride on Chloroplast Reactions. Environ. Lett., 6:175-191, 1974.

[d] Carrier, R.F. Chapter 8: Plant Interactions. In: Environmental, Health, and Control Aspects of Coal Conversion: An Information Overview. Vol. 2, H.M. Braunstein, E.D. Copenhaver, and H.A. Pfuder, eds. Information Center Complex, Information Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37830, 1977.

(continued)

TABLE A-II-3. (continued)

[e] Hampp, R., K. Beulich and H. Ziegler. Effects of Zinc and Cadmium on Photosynthetic CO_2-Fixation and Hill Activity of Isolated Spinach Chloroplasts. Z. Pflanzephysiol., 77(4):336-44, 1975.

[f] Boutet, C. and C. Chaisemartin. Specific Toxic Properties of Metallic Salts in _Austropotamobius_ _pallipes_ and _Orconectes_ _limosus_. C. R. Soc. Biol., 167(12):1933-1938, 1973.

[g] Unpublished information submitted to the U.S. Environmental Protection Agency under Contract No. 77-43-302073.

[h] Gray, J.S. and R.J. Ventilla. Growth Rates of Sediment-Living Marine Protozoan as a Toxicity Indicator for Heavy Metals. Ambio, 2(4):118-121, 1973.

[i] Callan, W.M. and F.W. Sunderman, Jr. Species Variations in Binding of ^{63}Ni (II) by Serum Albumin. Res. Commun. Chem. Pathol. Pharmacol., 5(2):459-472, 1973.

At the bottom of each background summary sheet, the actual calculations for both the MATE values and EPCs of the substances are given to indicate the derivation of figures entered in the MEG charts. Only the equations defining the lowest MATE values in each medium are presented. By displaying these calculations, the Background Information Summary offers the reader the opportunity to relate the values listed on the charts to the data from which they are derived.

All existing or proposed federal standards, criteria, or recommendations addressing chemical substances in ambient media are to be applied to define one set of Ambient Level Goals. When federal guidelines include more than one value specifying permissible ambient levels for a given compound, the most stringent standard is reflected in the MEG chart as the EPC entered in the appropriate column under the general heading "Current or Proposed Ambient Standards or Criteria." Information pertinent to the standards or criteria utilized in establishing EPCs is presented in the background information summaries under the section entitled "Regulatory Actions, Standards, Criteria, Recognition, Candidate Status for Specific Regulation."

A-II.1.4 MATEs for Totals

MATE values for specific chemical contaminants, although valuable, are not sufficient to characterize an environmentally acceptable waste stream. Ceiling values for certain totals associated with gaseous, aqueous, or solid waste are also required. Such totals are to be used in conjunction with the MATEs for specific chemical contaminants and provide a secondary check for contaminant levels.

Selection criteria for totals are:

(1) The parameter must be related to the presence of more than one chemical substance.

(2) The parameter must be federally regulated in some context. Federal guidelines surveyed for possible totals to be addressed include NAAQS, NSPS, effluent guidelines, drinking water standards, water quality criteria.

(3) The parameter must be measurable by some established method.

The following parameters are classified as totals to be addressed by MATEs. Ultimately, a MATE value will be specified for each total listed. MATE values for the land totals may be based on water MATE totals via a leaching model.

Air	Water	Land
Total hydrocarbons	Total suspended solids	Total leachable organics
Total particulates	Total dissolved solids	Total leachable substances
	Total organic carbon (TOC)	
	Biological oxygen demand (BOD)	
	Chemical oxygen demand (COD)	

Algorithms designed to generate EPCs and MATEs for specific chemical contaminants are not applicable to totals. Instead, attention must be given to each parameter in order to recommend a MATE value.

Values for totals will be recommended with consideration given to: (1) existing regulations and recommendations, (2) associated toxicity, (3) dilution factors expected at the site of dispersion of the effluent, and (4) the nature of the environmental problems associated with the substances indicated by the total.

A-II.1.5 Emission Level Goals Based on Ambient Level Goals

Emission Level Goals more stringent than MATEs are derived from Ambient Level Goals (which include the EPCs). Ambient Level Goals are presented in the lower half of the MEG chart. The most stringent values for each medium, based on health and on ecological effects, are then entered at the top of the MEG chart in the appropriate columns under Emission Level Goals based on Ambient Level Goals (II-B of Figure A-II-1). These values, multiplied by dilution factors, then describe control levels for emissions that will not cause contaminant concentrations in ambient media to exceed the suggested Ambient Level Goals.

Dilution factors are dimensionless quantities representing the ratio of the concentration of a contaminant in an emission or effluent to the resulting contaminant level in the ambient receiving medium. As an example, consider an emission from a stack discharged to the atmosphere. The dilution factor is the concentration of a pollutant in the stack gas divided by the resulting ground level concentration of the pollutant.

Since the dilution factors are variable and highly source specific, no effort has been made to provide the Emission Level Goals with dilution factors applied. Instead, the multiplication exercise is left to the person applying the charts to a specific industrial situation.

Although dilution factors do not appear on the MEG charts, consideration has been given to the range of factors likely to be encountered in most situations. In spite of the many parameters (listed below in Table A-II-4) affecting the magnitude of dilution factors, they may be expected to range between 10 and 10,000 for discharges to air and water. This range is suggested on the basis of the best- and worst-case models of pollutant dispersion.

A-II.1.6 Elimination of Discharge (EOD) Emission Level Goals

Emission Level Goals based on Elimination of Discharge, Column II-C, Figure A-II-1, like those based on Ambient Level Goals, incorporate dilution factors. These goals are the most stringent and imply that ambient concentrations of

TABLE A-II-4. PARAMETERS AFFECTING DILUTION FACTORS

Air	Stack flow
	Stack temperature
	Stack height
	Weather conditions: windspeed, sunlight, temperature, pressure
	Site topography
	Characteristics of discharge
	Photochemical reaction kinetics
Water	Flow rate of receiving stream
	Turbulence of receiving stream
	Temperature of receiving stream
	pH of receiving stream
	Flow rate of discharge
	Location and design of outfall
	Temperature of discharge
	Characteristics of contaminants in discharge: solubility, reactivity, pH, biodegradability, sorption characteristics
Land	Soil characteristics: permeability, pH, cation exchange capacity, weathering, sodium absorption ratio
	Characteristics of contaminants: ionization, leachability, biodegradability
	Characteristics of bulk solid waste: surface to volume ratio, density
	Method of disposition
	Climate: temperature, rainfall.

pollutants should not exceed natural background concentrations.

Values appearing on the MEG chart under Emission Level Goals, based on EOD, indicate natural background levels. Concentrations measured in rural atmosphere are entered for air. When rural atmosphere concentrations are not reported, urban or industrial concentrations may be entered on the chart with a footnote to characterize the value. Concentrations entered in the MEG chart for water are for surface waters unless otherwise specified. Levels identified in drinking water and in seawater are included, since they provide some indication of natural background concentrations.

A-II.1.7 Application of the MEGs

A system has been developed for assigning indicators (X, XX, or XXX) to designate potentially hazardous substances based on values generated by the MEG methodology. This system provides a simple means of identifying through cursory inspection those pollutants most likely to pose a human threat. The 216 substances which have currently been addressed by the MEG methodology have been ranked in this way and classified as relatively non-hazardous (no indicator), hazardous (X), very hazardous (XX), or most hazardous (XXX). All substances which have been ranked are found in Table A-II-5.

A-II.1.8 MEGs for Nonchemical Pollutants

Cornaby and coworkers (2) reported that nonchemical pollution factors such as heat, noise, microorganisms, and land usage can be adapted to the MEG approach. They also reported that complex effluents (i.e., entire waste streams) should be amenable to the MEG approach. Other factors such

TABLE A-II-5. RANKING OF THE MATERIALS ADDRESSED BY THE CURRENT MEGs ACCORDING TO POTENTIAL ENVIRONMENTAL HAZARD

MOST HAZARDOUS (XXX)

3-Methylcholanthrene
Beryllium
Chromium
Cadmium
Mercury
Dibenz(a,h)anthracene
N-Nitrosodimethylamine
Nickel
7,12-Dimethylbenz(a)anthracene
Benzo(a)pyrene
Antimony trioxide
Selenium
Arsenic
Arsine
Arsenic trioxide

VERY HAZARDOUS (XX)

Benz(a)anthracene
Dibenzo(a,i)pyrene
Cobalt
Nickel carbonyl
N,N'-Dimethylhydrazine
Diazomethane
Lead
Polychlorinated biphenyls
4,6-Dinitro-o-cresol
2,4,6-Trinitrophenol
Tetramethyllead
Alkyl mercury
Organotin
Thallium
Phosphorous
Phosphine
Antimony
Bismuth
Hydrogen selenide
Copper
Uranium
Ethyleneimine
N-Nitrosodiethylamine
Hydrazine

HAZARDOUS (X)

Monomethylhydrazine
Dibenz(a,j)acridine
Dibenz(a,h)acridine
Dibenzo(c,g)carbazole
Tetraethyllead
Aminotoluenes
1-Aminonaphthalene
2-Aminonaphthalene
Acrolein
Lithium
Lithium hydride
Barium
Germanium
Tellurium
Vanadium
Formaldehyde
Nickelocene
2,4-Dichlorophenol
N,N-Dimethylhydrazine
1,2-Diphenylhydrazine
Nitrobenzene
1-Chloro-2-nitrobenzene
Dinitrotoluenes
Xylenols
3-Nitrophenol
4-Nitrophenol
Dinitrophenols
Pyridine
Gallium
Hydrogen cyanide
Manganese
Copper-8-hydroxyquinoline
Silver
4-Aminobiphenyl
Benzene
4-Nitrobiphenyl

(continued)

TABLE A-II-5. (continued)

RELATIVELY NONHAZARDOUS (NO INDICATOR)

1-Phenyl ethanol
Ethylene glycol
Formic acid
Phthalic acid
Tetramethylsuccinonitrile
Ethanolamine
Butylamines
p-Dimethylaminoazobenzene
Methanethiol
Ethanethiol
n-Butanethiol
Biphenyl
Phenathrene
Chrysene
Methylchrysenes
Benzo(e)pyrene
Picene
Dibenzo(a,h)pyrene
Dibenzo(a,l)pyrene
Benzo(j)fluoranthene
Benzo(b)fluoranthene
Indeno(1,2,3-cd)pyrene
Phenyl phenols
Isophorone
Formamide
Aniline
Phenol
Cresols
Alkyl cresols
Catechol
2-Chlorophenol
2-Nitrophenol
1-Chloro-2,3-epoxy propane
Naphthalene
2,2'-Dichloroethyl ether
Tertiary pentanol
Propionaldehyde
Acetic acid
Hydroxyacetic acid
Acetonitrile
Acrylonitrile
Benzonitrile
Cyclohexylamine
Dimethylamine
Quinoline, isoquinoline
Pyrrole
Dibenzo(a,g)carbazole
Thiophene
Methyl thiophenes
Potassium
Magnesium
Magnesium oxide
Strontium
Boron
Boron oxide
Aluminum
Aluminum oxide
Alkali cyanide
Hydrogen sulfide
Titanium
Molybdenum
Tungsten
Zinc
Benzidine
α-Chlorotoluene
Vinyl chloride
Benzo(c)phenanthrene
Pyrene
Benzo(c)phenanthrene
Dibenz(a,c)anthracene
Benz(c)acridine
Dibenz(c,h)acridine
Dibenzo(a,i)carbazole
Methanol
Ethanol
1,4-Dichlorobenzene
Indanols
Tetrahydrofuran
Methane
Ethane
Propane
Butanes
Ethylene
Propylene
Acetylene
Methyl chloride
Methalene chloride
1,4-Dioxane

(continued)

TABLE A-II-5. (continued)

RELATIVELY NONHAZARDOUS (NO INDICATOR) CONTINUED

Dimethylaniline
N,N-Dimethylaniline
Benzenesulfonic acid
Indene
Nitrotoluenes
Fluoranthene
Picolines
Collidines
Methylquinolines
Methylisoquinolines
Acridine
Indole
Carbazole
Benzo(b)thiophene
Ferrocene
Carbon monoxide
Ammonia
Ozone
Carbon disulfide
Scandium
Anthracene

n-Butanols
Isobutyl alcohol
Pentanols (primary)
2-Propanol
2-Butanol
Pentanols (secondary)
Tert-butanol
Acetaldehyde
Butyraldehyde
Benzoic acid
Toluene
Ethyl benzene
Indan
Xylenes
Tetrahydronaphthalene
Chlorobenzene
1,2-Dichlorobenzene
2-Chlorotoluene
Carbon dioxide
Carbonyl sulfide

The following compounds have not been assigned hazard potential values:

Naphthacene
Triphenylene
Dimethyl pyrenes
Perylene
Benzo(g,h,i)perylene

Coronene
Fluorene
2,3-Benz-4-azafluorene
Phosphate

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as radionuclides, electromagnetic radiation, and water usage may also be amenable to the MEG approach.

With regard to the heat effect, Cornaby and coworkers (2) suggested that the ambient air MEG be a wet bulb globe temperature of 30°C. The MEG for water should be 2.8°C above the "natural" or ambient temperature for the body of water. The ambient air temperature MEG should be based on physiological factors to assure human survival, assuming continuous light work and proper precautions to avoid the effects of water and salt depletion. The temperature MEG for water is thought to be sufficient to protect most aquatic populations from the many biological effects associated with elemental waste temperatures.

Noise values were judged to be adaptable to the MEG format. A level of 60 dB(A) was recommended as a reasonable environmental objective. This is the approximate noise emitted by an air conditioner 6 meters away. The noise of freeway traffic at 15 meters (70 dB(A)) makes telephone use difficult and can contribute to hearing impairment. Adverse effects due to noise include physiological stress reaction, sleep disturbance, and simple annoyance. The suggested standard is dropped to 45 dB(A) for noise between the hours of 10 p.m. and 7 a.m., since significant proportions of the populations experience sleep disturbances, difficulty in communication, and subjective annoyance in the range 45-65 dB(A). Studies have indicated that animals other than humans would not be stressed by this noise level.

The coal liquefaction process is not thought capable of significantly increasing the microbial populations of effluents, since the high process temperatures should effectively sterilize the products and effluents. However, the increase in ambient temperatures may favor the growth of microorganisms and/or population changes resulting in decreased species diversity. It is hoped that the temperature-related MEG mentioned previously should minimize this problem. The drainage from coal piles is thought to be of little concern with respect to microbial contamination, since its very low pH inhibits the growth of all but a few acidophilic bacteria. The dry, spent sorbent itself is too barren to support human pathogenic microorganisms.

There is probably a hazard to health and ecological systems from microbe-laden aerosols emanating from the cooling towers. However, the magnitude of the problem is not yet documented. It is generally assumed that bacteria are concentrated 4 to 5 times in the cooling towers. The droplets of less than 10 micrometers in diameter are important because of their drift characteristics and inhalation potential. The survival of harmful microorganisms in these aerosol droplets is not well defined. Viability was found to be reduced 96.8 percent at a point 47 m downwind; however, significant levels were still obtained 200 m downwind. Other factors such as increased humidity and larger particle size would tend to increase survival time. Chlorination would decrease counts in the make-up waters more than counts in the aerosol. Chlorination sufficient to kill coliforms may not kill other bacteria such as amoebic cysts and viruses.

In summary, significant numbers of microorganisms are capable of surviving and traveling considerable distances in aerosols. No literature was uncovered on the toxicity of microbe-laden aerosols to any living system, including man. Without this information and the species of microorganisms present in the aerosols, no defensible MEG value can be advanced. Perhaps each risk will have to be determined on a site-specific basis. Factors such as temperature, humidity, composition of water, use of biological controls, microbial drift, and biological effects must be analyzed for each operation.

Entire emission streams (i.e., complex effluents) should be amenable to the MEG approach. However, the lack of information on the ecotoxicological effects of complex effluents prevents such calculations.

Some significant mortality/morbidity studies have been performed and are summarized in Table A-II-6. This type of information lends itself to the development of MEGs for impacts on human health; however, more statistical analyses of such studies need to be performed in order to define a specific MEG. Mortality studies are currently being performed on the entire coal cycle by the Brookhaven and the Argonne National Laboratories of the U.S. Department of Energy.

Land usage can be adapted to the MEG format. There are many ways of measuring land usage, such as density of human and non-human organisms, and a MEG chart should be developed for each. The rationale for using the density of animals to determine which land tract should be developed is that the lower the density is, the fewer people and organisms to be impacted. The wildlife density is related to the quality of the habitat. The value of 62 or fewer individual wildlife organisms of those species listed in Table A-II-7 per 40 hectares was chosen to indicate land having poor wildlife habitat.

A-II.2 Existing Environmental Regulations

Tables A-II-8 through A-II-12 and the accompanying discussion summarize existing federal and state multimedia environmental regulations.

TABLE A-II-6. EPIDEMIOLOGICAL MORTALITY/MORBIDITY STUDIES[a]

Response	Pollution Specifics	Human Sub-Population	
		Exposed	Non-Exposed
Infant Mortality	Daulphin Co., PA., U.S.A. General Air Pollution	1. Infants born during high air pollution months (July, August, September) represented 50%(+) of the total annual infant mortality or 18% of infant deaths/month. (66 cases)	1. The study demonstrated thru matched pairs that those born during non-pollution alerts had lower mortality. (~5% of infant deaths/month)
Infant Mortality	Nashville, TN, U.S.A. City Air: Means ($\bar{X}$) 22.4 mg/m^2/ton - Sulfation 2.559 gm/m^2/month - Dustfall 1.65 COHS/km - Soiling 0.0075 24 hr ppm - 24 hr SO_2 Country air not reported (assumed to be less).	1. White neonatal mortality ratio (1960) of 18.2/1,000 live births.	1. White neonatal mortality ratio for neighboring rural county: 14.0/1,000 (U.S.A. avg. is 10.3/1,000).
Adult Mortality	Coal fired electric power plant in PA, U.S.A. 151 μg/m^3 suspended particulate 3.70 mg/m^2/day sulfation rate Exposed was 9 x SO_2 6.2 x sulfation rate, 3.2 x dust fall, and 1.4 x suspended particles that of unexposed.	Town of Seward, PA. 1. Sex & age adjusted death rate of Seward exceeded that of New Florence for 10 out of 11 years. (≤ .05) 2. Three times as many expected cirrhosis deaths.	Town of New Florence, PA. (see exposed)
Morbidity (chronic destructive pulmonary disease)	Ontario, Canada Nickel & Copper Smelter Exposed 32.5 ppb - SO_2 52.1 μg/m^3 - Suspended particulate Non-Exposed 16.1 ppb - SO_2 90.5 μg/m^3 - Suspended particulate	Town of Sudbury: 1. Male prevalence rate of 112/1,000 for chronic bronchitis. 2. Total male & female prevalence rate of 97/1,000. 2208 people studied.	Town of Ottawa: 1. Male prevalence rate of 81/1,000 for chronic bronchitis. Total male & female prevalence rate of 77/1,000. 3280 people studied.
Morbidity (pulmonary function testing)	Ohio, U.S.A. Urban - Industrial (exposed) 10.1 g/m^3/day - SO_3 40.98 g/m^2/month - dust fall 109.27 μg/m^3/24 hr - total suspended particles) Rural (Non-Exposed) 7.6 - SO_3 2.10 - dust fall 83.30 - total suspended particles	1. The vital capacity (VC) & Forced Expiratory Volume (FEV) 0.75 are significantly lower than for students in rural areas (173 people studied).	1. Higher VC & FEV's than urban population. (161 people studied)

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[a] Cornaby, B.W., D.A. Savitz, M.E. Stout, G.E. Pierce, and A.W. Rudolph. Development of Goals for Nonchemical and Nonpollutant Factors in Fluidized-Bed Combustion -- Draft Report. Technical Directive 31, Contract No. 68-02-2138, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, 1977.

TABLE A-II-7. DENSITIES OF WILDLIFE SPECIES IN VARIOUS HABITATS IN KENTUCKY

Species	Habitat quality, no./40 hectares			
	Poor	Fair	Good	Excellent
Deer	2	3	4	7
Squirrel	33	40	66	100
Grouse	4	5	7	14
Turkey	1	1	2	5
Quail	12	17	25	50
Rabbit	12	25	50	100
Totals	64	91	154	276

TABLE A-II-8. MAJOR STATIONARY SOURCES SUBJECT TO PSD REVIEW (5)

Power plants greater than 73 million W/h

Specific sources greater than 91 megagrams/y any pollutant

Power plants
Coal cleaning plants
Kraft pulp mills
Portland cement plants
Primary zinc smelters
Iron and steel mill plants
Primary aluminum ore reduction plants
Primary copper smelters
Municipal incinerators greater than 227 megagrams/day
Hydrofluoric acid plants
Sulfuric acid plants
Petroleum refineries
Lime plants
Phosphate rock processing plants
Coke oven batteries
Sulfur recovery plants
Carbon black plants (furnace process)
Primary lead smelters
Fuel conversion plants
Sintering plants
Secondary metal production facilities
Chemical process plants
Fossil-fuel boilers greater than 73 million W/h
Petroleum storage and transfer facilities greater than 47,695 m^3
Taconite ore processing facilities
Glass fiber processing plants
Charcoal production facilities

Any other source greater than 227 megagrams/y any pollutant

TABLE A-II-9. LISTING OF 65 CLASSES OF TOXIC POLLUTANTS (3)

1. Acenaphthene
2. Acrolein
3. Acrylonitrile
4. Aldrin/dieldrin
5. Antimony and compounds[a]
6. Arsenic and compounds
7. Asbestos
8. Benzene
9. Benzidine[b]
10. Beryllium and compounds
11. Cadmium and compounds
12. Carbon tetrachloride
13. Chlordane (technical mixture and metabolites)
14. Chlorinated benzenes (other than dichlorobenzenes)
15. Chlorinated ethanes (including 1,2-dichloroethane, 1,1,1-trichloroethane, and hexachloroethane)
16. Chloroalkyl ethers (chloromethyl, chloroethyl, and mixed ethers)
17. Chlorinated naphthalene
18. Chlorinated phenols (other than those listed elsewhere; includes trichlorophenols and chlorinated cresols)
19. Chloroform
20. 2-chlorophenol
21. Chromium and compounds
22. Copper and compounds
23. Cyanides
24. DDT and metabolites[b]
25. Dichlorobenzenes (1,2- 1,3-, and 1,4-dichlorobenzenes)
26. Dichlorobenzidine
27. Dichloroethylenes (1,1-, and 1,2-dichloroethylene)
28. 2,4-dichlorophenol
29. Dichloropropane and dichloropropene
30. 2,4-dimethylphenol
31. Dinitrotoluene
32. Diphenylhydrazine
33. Endosulfan and metabolites
34. Endrin and metabolites[b]
35. Ethylbenzene
36. Fluoranthene
37. Haloethers (other than those listed elsewhere; includes chlorophenylphenyl ethers, bromophenylphenyl ether, bis(dichloroisopropyl) ether, bis-(chloroethoxy) methane and polychlorinated diphenyl ethers)
38. Halomethanes (other than those listed elsewhere; includes methylene chloride methylchloride, methylbromide, bromoform, dichlorobromethane, trichlorofluoromethane, dichlorodifluoromethane)
39. Heptachlor and metabolites
40. Hexachlorobutadiene
41. Hexachlorocyclohexane (all isomers)
42. Hexachlorocyclopentadiene
43. Isophorone
44. Lead and compounds
45. Mercury and compounds
46. Naphthalene
47. Nickel and compounds
48. Nitrobenzene
49. Nitrophenols (including 2,4-dinitrophenol, dinitrocresol)
50. Nitrosamines
51. Pentachlorophenol
52. Phenol
53. Phthalate esters
54. Polychlorinated biphenyls (PCBs)[b]
55. Polynuclear aromatic hydrocarbons (including benzanthracenes, benzopyrenes, benzofluoranthene, chrysenes, dibenzanthracenes, and indenopyrenes)
56. Selenium and compounds
57. Silver and compounds
58. 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD)
59. Tetrachloroethylene
60. Thallium and compounds
61. Toluene
62. Toxaphene[b]
63. Trichloroethylene
64. Vinyl chloride
65. Zinc and compounds

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[a] The term "compounds" shall include organic and inorganic compounds.

[b] Effluent standard promulgated (40 CFR Part 129).

TABLE A-II-10. SPECIFIC POLLUTANT LIMITATIONS (4)

Substance	NAAQS (Primary standard) mg/m^3	OSHA^1 mg/m^3	NESHAP (Hazardous air pollutant)	NSPS	Motor vehicles (light duty vehicles)	Drinking water^2 mg/l	Effluent standards (one day maximum)
Ammonia		35 (18)					0.0126 g per kg of product^3
Arsenic		0.5				0.05 (0.01)	1.0 mg/l^4
Asbestos		5 fibers/cc; fiber length >5 μm	No visible emission; controls specified				No discharge of process wastewater pollutants to navigable waters^5
Barium		0.5				1.0	0.009 g per kg of product^6
Benzidine		Qualitative regulation (human carcinogen)					
Beryllium		0.002	10 g/24 hrs^7				
Cadmium		0.1 (0.05)				0.01	0.10 mg/l^8
Carbon monoxide	10 (8 hrs)	55	0.05% by volume^7		3.4 g/mile		
Chlorine; chlorides		Chlorine: 1.0				Chloride: (250)	Free available (CN) 0.5 mg/l^9
Chromium (Cr)		Soluble: 0.5				0.05	Hexavalent Cr: 0.015 g/m^3 of feedstock^{11}
Coliform bacteria						1 bacteria per 100 ml	400 counts per 100 mls (any time)^{12}
Copper		Dust: 1, Fume: 0.01 (0.2)				(1.0)	0.1 mg/l^{13}
Cyanide		5				(0.01)	0.0003 g per kg of product^3
Fluorides		2.5		5 g metric ton of P_2O_5 feed^{12}		1.4-2.4 (related to temperature)	0.0126 g/kg of product^{15}
Hydrocarbons	Nonmethane hydrocarbons: 0.16 (3-hr)	Hexane: 360 Pentane: 1800 Butane: 1450 Octane: 1450 Heptane: 1600		Control technology specified related to vapor pressure of hydrocarbons^{16}	Hydrocarbons: 0.41 g/mile		
Hydrogen sulfide; sulfide		20 ppm ceiling (15; 15 ppm ceiling)		Total reduced sulfur: 5 ppm by volume^{18}			Sulfide: 0.0003 g per kg of product^3
Iron		Iron-oxide fume: 10 (5.0)				(0.3)	Total: 7 mg/l dissolved: 0.6 mg/l^{19}
Lead		0.2 (0.15)				0.05	0.4 mg/l^{11}
Manganese		5				(0.05)	4.0 mg/l^{19}
Mercury		0.1 ceiling (0.01)	2300 g/24 hrs^{20}			0.002	0.002 mg/l^{11}
Nickel		1.0 (0.1)					0.006 g per kg of product^{21}

(continued)

TABLE A-II-10. (continued)

Substance	NAAQS (Primary standard) mg/m^3	OSHA[1] mg/m^3	NESHAP (Hazardous air pollutant)	NSPS	Motor vehicles (light duty vehicles)	Drinking water[2] mg/l	Effluent standards (one day maximum)
NO_x; nitrate	NO_2: 0.1 (annual)	NO_2: 9		NO_2: 0.20 lb per 10^6 Btu of heat input derived from solid fossil fuel[22]	NO_2: 2.0 g/mile	Nitrate: 10 (45)	0.017 g per kg of product[23]
Oil and/or grease		Mineral oil mist: 5					20 mg/l
Osmium		0.002					16 mg/m^2 of production[27]
Ozone (oxidants)	0.16 (1 hr)	0.2					
Particulates	0.075 (annual)	Nuisance particulate: 15. (10.)		0.1 lb per 10^6 Btu input derived from fossil fuel[22] 0.04 g/dscm[25]			Total suspended solids: 70/mg/l[19]
Phenol, phenolic compounds		Phenol: 19				Phenols: (0.001)	0.0006 g per kg of product[3]
Phosphorous		Elemental, yellow: 0.1					105 g per kg of product[26]
Platinum		0.002					16 mg per kg of product[27]
Rhodium		Soluble salts: 0.001					16 mg per m^2 of product[27]
Selenium		0.2				0.01	0.0015 g per kg of product[21]
Silver		0.01				0.05	0.001 g per kg of product[28]
SO_2, sulfate	SO_2: 0.08 (annual)	SO_2: 18		SO_2: 1.2 lb per 10^6 Btu of heat input derived from solid fossil fuel[22] 2 kg per metric ton of acid produced[29]		Sulfate: (250)	
Tin		Inorganic: 2 organic: 0.1					160 mg per m^2 of product[27]
Uranium		Soluble: 0.05 Insoluble: 0.25 (all: 0.2)					4 mg/l[4]
Vinyl chloride		1 ppm (200 ppm)	10 ppm				
Zinc		$ZnCl_2$ fume: 1 ZnO fume: 5				5	0.003 g per kg of products[15]

(continued)

TABLE A-II-10. (continued)

FOOTNOTES

1. Value in parentheses is 1976 ACGIH TLV; given only if value is different from existing OSHA standard.
2. Value in parentheses is for 1968 Public Health Service Drinking Water Standards; value is given only if different from Primary Drinking Water Regulation.
3. Iron and Steel, By-Product Coke: (BAT, NSPS).
4. Ore Mining and Dressing, Uranium, Radium, Vanadium Ores: Mine Drainage: (BPT).
5. Asbestos Manufacturing: (BAT, NSPS).
6. Inorganic Chemicals, Potassium Iodide Production: (BPT).
7. Based on ambient level of 0.01 $\mu g/m^3$.
8. Ore Mining and Dressing, Base and Precious Metals: From Mills: (BPT).
9. Petroleum Refining, Catalyst Regenerator-Fluid Catalytic Cracking Unit.
10. Steam Electric Power Generating, Generating Unit: From cooling tower blowdown: (BPT, BAT, NSPS).
11. Petroleum Refining, Topping: (NSPS).
12. Canned and Preserved Fruits and Vegetables, Citrus Products: (BAT, NSPS).
13. Ore Mining and Dressing, Base and Precious Metals: From Mine Drainage or Mills: (BPT).
14. Phosphate Fertilizer Industry.
15. Iron and Steel, Open Hearth Furnace: (BAT, NSPS).
16. Storage Vessels for Petroleum Liquid.
17. Oil and Gas Extraction, Offshore: (BPT).
18. Kraft Pulp Mills (proposed).
19. Coal Mining, Mine Drainage: (BPT).
20. Based on recommended ambient level of 1 $\mu g/m^3$.
21. Inorganic Chemicals, Copper Sulfate Production: (BPT).
22. Fossil Fuel-Fired Steam Generators.
23. Fertilizer Manufacturing, Nitric Acid: (BAT).
24. Steam Electric Power Generating, Generating: (BPT, BAT, NSPS).
25. Coal Preparation Plants, Pneumatic Equipment.
26. Fertilizer Manufacturing, Phosphate: (BPT, BAT, NSPS).
27. Electroplating.
28. Inorganic Chemicals, Silver Nitrate Production: (BPT).
29. Sulfuric Acid Plants.

TABLE A-II-11. MONITORING REQUIREMENTS FOR ISSUANCE OF PERMITS (5)

Activity	Time required	Cumulative
Specify monitoring required	1-2 months	1-2 months
Select vendors & contractors	1-3 months	2-5 months
Procure and install equipment	1-4 months	3-9 months
One-year baseline monitoring	12 months	15-21 months
Complete data analysis and modeling	1-4 months	16-25 months
(Permit application complete) Request special model, with agency hearing and review (if necessary)	2-6 months	18-31 months
Hearings on application and final agency review	3-12 months	21-43 months

TABLE A-II-12. PRINCIPAL EPA RULEMAKING RELATIVE TO STATIONARY SOURCES (5)

Action	Statutory deadline
Listing of AQCRs by attainment status	February 1978
Short-term NO_2 standard	February 1978
Stack height regulations (limiting credit to 2-1/2 times the height of the source)	February 1978
Analysis requirements in PSD areas	February 1978
Revised NSPS for fossil boilers	August 1978
Ozone protection regulations	November 1979
PSD regulations for other criteria pollutants (NO_x, CO, SO_x, HC)	August 1979
Visibility protection regulations	November 1979
NSPS for stationary sources	August 1979 - August 1982*

*EPA is required to list major stationary source categories for NSPS by August 1979 and promulgate NSPS for 25%, 75% and 100% of list by August 1981, 1982, and 1983, respectively.

A-II.2.1 Monitoring and Modeling Requirements in PSD Areas

The time schedules required for the collection of data to be reported by applications for new facility permits are shown (conservatively) in Table A-II-11. Baseline monitoring is required at the site of new activities to establish the baseline air quality. The impact of the proposed facilities will be assessed for the short-term PSD increments by use of air quality modeling to evaluate the meteorologic or topographic conditions in a region that has the highest expected concentration of pollutants. The EPA was required to issue regulations for the evaluation of facilities proposed for PSD areas, including the required air quality models.

Since August 1978, about one year of baseline air quality monitoring has been required as a part of the permitting process for all new facilities and modifications of existing facilities.

On February 2, 1978, the DOE Office of Coal and Utility Policy recommended that baseline concentrations for calculation of PSD increments should be determined at the time of the first permit application in a given area. This was in contrast to the EPA proposal that such baseline concentrations be determined as of January 6, 1975. The DOE also suggested that the 45 megagrams per year exemption from PSD analysis be extended to new and modified stationary sources in Class II, III, and nonattainment areas. The DOE recommended that the major stationary sources not on the list of industrial category types should be analyzed at 227 megagrams per year or more, rather than for all pollutants emitted at 91 megagrams or more per year as reported by the EPA (6).

A-II.2.1.1 Sharing of PSD Increments

Individual new facilities will have to share the PSD increments among adjacent or nearby stationary sources. Thus, the permitted emission rates for each facility will be lower than for the case where a facility was evaluated apart from a potential future major industrial neighbor (5). A related policy issue refers to the required separation distance between facilities in deciding whether to assess the impacts of each facility independently rather than additively. Thus, it is conceivable that the production capacity and size of a major facility may have to be curtailed, or stringent pollutant controls may be required for SO_2 and TSP. This issue may be seriously confounded in 1979, when PSD regulations will be issued by the EPA for CO, NO_x, photochemical oxidants, and hydrocarbons. Principal EPA rulemaking deadlines are shown in Table A-II-12.

A-II.2.1.2 Visibility and Other Air-Quality-Related Values

The visibility issue likely will serve as the primary factor affecting variances from the Class I increment limits (see Chapter 2, Table 2-1). Other items that might qualify are fugitive emissions, odors, air pollutant effects on crop yields, and microclimatic changes. The EPA is required to issue visibility regulations by November 1979 to enforce a national goal of visibility protection, as specified in PL95-95.

A-II.2.1.3 Nonattainment Areas

Until July 1, 1979, construction permits for major new stationary sources in nonattainment areas will be issued in accordance with EPA's 1976 Interpretive Ruling on emission offsets. Under some conditions, states may be granted waivers to this policy. According to the emission offset policy, new sources that have the potential to emit 91 megagrams per year of any pollutant will be given a construction permit, provided that:

- Emissions from existing areas are reduced by an amount sufficient to offset emissions from the new plant.
- The proposed plant attains the Lowest Achievable Emission Rate (LAER).
- The emission offsets obtained produce a positive net air quality benefit.
- All of the applicant's existing facilities in the AQCR are in compliance with applicable emission standards.

Before a major new source may locate in a nonattainment area, each state, after June 30, 1977, must have revised its implementation plan (SIP) to attain primary ambient air quality standards by December 31, 1982. An extension of five years (to December 31, 1987) will be available to areas having CO or photochemical oxidant problems. Because new sources shall be included in each SIP, new sources operators are advised to divulge their construction plans to the applicable state permitting offices at the earliest date.

The State of Texas recently made the first official application to the EPA requesting a waiver of the requirements of the federal emissions offset policy. In this regard, Texas would be allowed to administer its own growth policy, provided that in-place programs could assure incremental emission reductions in compliance with the national ambient air quality standards by 1982. The granting of this request would establish a precedent (7).

The EPA stated in September 1977 (7) that all areas east of the Mississippi River are now presumed to be in violation of the ambient air quality standard for photochemical oxidants. This presumption was not a flat mandate, but provided guidance to states in locating which areas met or exceeded the federal standards. In effect, the action should assist the states in deciding which air pollution control requirements apply. Rural fugitive dust will be discounted in establishing attainment status for total suspended particulates.

The following guidelines are applicable to TSP, SO_2, CO and photochemical oxidants:

- Total suspended particulates: The area should be designated attainment when a TSP violation can be clearly attributed to rural fugitive dust.

- Total suspended particulates and sulfur dioxide: In cases where an area is unclassifiable or is designated as attainment, major new or modified sources must be reviewed to ensure consistency with PSD requirements.

- Carbon monoxide: Specific areas covered by monitors showing violations should be designated as nonattainment; however, SIP revisions covering larger geographic areas may be necessary to solve the nonattainment problem.

- Photochemical oxidants: Ambient data in the eastern U.S. and Midwest show widespread violation of the standards. This pervasive problem has been demonstrated by research studies to be due largely to transport from urban areas. This transported ozone has been shown to persist at levels well in excess of the standard for hundreds of miles downwind of urban areas. Therefore, in the absence of data showing attainment, all areas east of the Mississippi River should be presumed nonattainment. The fact that ozone is transported from urban areas will be recognized in the development of policies related to SIP content and approval. Additional monitoring will be required for areas designated as not classifiable pursuant to Section 107(d)(1)(E). If data showing nonattainment become available, the appropriate change to the attainment status must be made.

On August 16, 1977, the EPA advised regional administrators of a new policy for controlling fugitive dust emissions. Priority will be given to urban areas for development of comprehensive and reasonable controls of industrial particulates. In rural areas, control of fugitive dust would center on sources such as coal piles and mining operations shown to be causing violations of the NAAQS, as sources of known toxic or hazardous substances (8). This policy allows those who wish to construct new stationary sources to do so without concern for emission offsets.

A-II.2.2 Other Federal Statutory Requirements

Section 311 of the Clean Water Act concerns oil and hazardous substance liability. This item will be of particular significance to the coal conversion technology. While no hazardous substances have been designated by the EPA under this section, they have developed a list of some 300 chemicals and constituents of oil. Section 311(c) of the Act stipulates the development of a National Contingency Plan to minimize damage to the aqueous environment from oil and hazardous substance discharges. Action plans for containment, dispersal, and removal are required, with particular reference to the discharge of oil and hazardous substances which may affect natural resources belonging to or under the exclusive management authority of the United States and those under the Fishery Conservation and Management Act of 1976 (9).

The Marine Protection Research and Sanctuaries Act of 1972 controls the ocean dumping of matter of any kind, including radioactive materials (but excluding oil), sewage from vessels, and effluents regulated by FWPCA, the 1899 Rivers and Harbors Act, or the Atomic Energy Act. Permits may be issued by the EPA for the transportation and dumping of materials (other than radiological, chemical and biological warfare agents, and dredged material) should the Administrator conclude that such dumping will not unreasonably endanger or degrade human health and welfare.

The Resource Conservation and Recovery Act of 1976 controls water pollution indirectly by requiring a regulatory system for the treatment, storage, and disposal of hazardous wastes. Hazardous waste is defined as a solid waste generated by industrial, commercial, mining and agricultural operations that, because of its quantity or characteristics (e.g., bottom ash or fly ash containing radioactivity and suspected carcinogens), may be hazardous to human health or to the environment. Subtitle C of the 1976 Act requires the EPA administrator to:

- Promulgate criteria and regulations that identify the characteristics of hazardous waste, and list particular hazardous waste

- Promulgate standards, regulations, and manifests applicable to those who generate, transport, treat, store, or dispose of hazardous wastes. These procedures will specify record keeping, labeling, reporting, monitoring and inspection practices, and compliance with requirements for permits. Also required is the promulgation by the EPA of guidelines to assist the development of state hazardous waste programs. These programs must fulfill the criteria of consistency, equivalency, and adequacy of enforcement. For example, regulations developed by EPA relative to transporters of hazardous wastes subject to the Hazardous Materials Transportation Act, must be consistent with the requirements of that Act. EPA must also integrate all provisions of the Resource Conservation Act and avoid duplication (where practicable) with the Clean Air Act, the Clean Water Act, Safe Drinking Water Act, and other acts that grant regulatory authority to EPA.

The Toxic Substances Control Act (TSCA) of 1976 authorizes the EPA to require the testing of suspected chemicals to determine the extent of the toxicity. This broad discretionary power is highly relevant to certain potentially toxic inorganics and organics known to occur in certain waste streams and products of the SRC technology. The EPA administrator may prohibit or limit the disposal of a chemical or a mixture of chemical substances, when he finds that there is a reasonable basis to conclude that a chemical substance or a mixture poses an unreasonable risk of injury to human health or to the environment as a whole. The term "chemical substance" means any inorganic or organic substance of a particular molecular identity. The term "mixture" is defined as a combination of chemical substances that is not the result of a chemical reaction.

The major importance of TSCA is that it stands as an alternative statutory control, if adequate controls cannot be developed for a chemical substance through the Clean Water or Safe Drinking Water Act (9).

A-II.2.3 State Requirements

Table A-II-13 outlines state standards for hazardous substances in surface waters.

TABLE A-II-13. NON-NUMERICAL STANDARDS AND CRITERIA FOR HAZARDOUS SUBSTANCES IN SURFACE WATERS

Region and state	Applicable non-numerical standards and criteria
Four Corners Region	
1. Arizona	All surface waters shall be free from toxic, corrosive, or other deleterious substances attributable to industrial waste at levels or combinations sufficient to be toxic to human, animal, plant or aquatic life. As a minimum evaluation for the presence of toxic substances, use a 96-hour bioassay based on "Standard Methods for the Examination of Water and Wastewater." Survival of test organisms shall not be less than that in controls which utilize appropriate experimental water.
2. Colorado	All state waters shall be free from substances attributable to ... industrial, or other discharges ... which are toxic or harmful to human, animal, plant, or aquatic life.

(continued)

TABLE A-II-13. (continued)

Region and state	Applicable non-numerical standards and criteria
3. Utah	State waters shall be free from ... toxic, corrosive, or other deleterious substances attributable to ... industrial waste or other controllable sources at levels of combinations sufficient to be toxic to human, animal, plant or aquatic life or in amounts sufficient to interfere with any beneficial use of the water.
Fort Union-Powder River	
1. Montana	Industrial waste shall receive, after maximum practicable in-plant control, a minimum of secondary treatment or equivalent ..., and control of toxic or other deleterious substances before discharge into state waters. State surface waters are to be free from substances attributable to ... industrial ... or other discharges that will create concentrations or combinations of materials which are toxic or harmful to human, animal, plant, or aquatic life ... Bioassay median tolerance concentrations are to be based on latest available research results for the materials, by bioassay test procedures for simulating actual stream conditions as set forth in the latest edition of Standard Methods for the Examination of Water and Wastewater published by the American Public Health Association ...
2. North Dakota	All waters of the state shall be ... free from substances attributable to ... industrial, or other discharges ... in concentrations or combinations which are toxic or harmful to human, animal, plant, or resident aquatic life.
3. South Dakota	Toxic materials prohibited. No materials shall be discharged or caused to be discharged to any lake or stream which produce concentrations of chemicals toxic to humans, animals, plants, or the most sensitive stage or form of aquatic life, greater than 0.1 times the median tolerance limit for short residual compounds or 0.01 times the median tolerance limit for an accumulative substance or substances exhibiting a residual life exceeding thirty days in the receiving waters. Median tolerance

(continued)

TABLE A-II-13. (continued)

Region and state	Applicable non-numerical standards and criteria
3. South Dakota (continued)	limits shall be determined in accordance with section 34:04:02:06. Concentrations specified for toxic materials shall be based on daily averages, but the concentrations shall not exceed one hundred and twenty-five percent of the value specified in this section at any time or at any point in the receiving water. Exceptions to prohibition of toxic materials arise where a numerical criterion has already been established for: a toxic substance relative to cold water or warm water for fish life propagation; immersion recreation waters; limited contact recreation waters; wildlife propagation waters; irrigation waters; commerce and industry waters, and trout fishery waters.
4. Wyoming	Any person owning or having control over ... hazardous material that is (discharged) into public waters ... shall: • Immediately stop the discharge • Immediately collect and remove the ... hazardous material unless not feasible, in which case the person shall take all practicable actions to contain, treat, and disperse the same in a manner acceptable to the Wyoming Department of Environmental Quality in coordination with the U.S. Environmental Protection Agency and in accordance with Annex X of the National Contingency Plan. Cleanup of ... hazardous material spills shall proceed in a timely and diligent manner until official notice is obtained from the Water Quality Division of the Wyoming DEQ that satisfactory cleanup has been achieved. Disposal of hazardous materials shall be done in accordance with procedures approved by the Water Quality Division of the Wyoming DEQ.
Appalachian Region	
1. Kentucky	All waters of the Commonwealth of Kentucky shall be:

(continued)

TABLE A-II-13. (continued)

Region and state	Applicable non-numerical standards and criteria
1. Kentucky (continued)	• Substantially free from substances attributable to ... industrial or other discharges ... that will settle to form putrescent sludge deposits. • Free from substances attributable to ... industrial or other discharges ... in concentrations or combinations which are toxic or harmful to human, animal, plant, or aquatic life.
2. Ohio	• Furnish the Ohio Department of Health, Division of Engineering, with a list of all chemicals and materials which are toxic. • Construct emergency holding facilities to prevent discharge of wastewater which may be accidentally contaminated with toxins. Toxins are defined as materials that contain toxic constituents.
3. Virginia	All state waters shall be free from substances attributable to ... industrial waste, or other waste in concentrations, amounts, or combinations which ... are inimical or harmful to human, animal, plant, or aquatic life. Specific substances to be controlled include, but are not limited to: ... toxic substances, substances that ... settle to form sludge deposits, and heated substances.
4. West Virginia	The State Water Resources Board declares it mandatory that, in order to minimize the adverse effect which the spills and accidental discharges of ... industrial wastes may have upon users of water of the State, the following procedures shall be followed: • Each and every municipality, corporation, person or other entity which or who may cause or be responsible for any spill or accidental discharge into the waters of the State, of sewage, industrial waste or other substance of such character and in such quantity as to be unsightly or deleterious to the quality of such waters shall give prompt notification thereof by telephone to the Chief of the Division of Water Resources, State Department of Natural Resources, or an employee thereof;

(continued)

TABLE A-II-13. (continued)

Region and state	Applicable non-numerical standards and criteria
4. West Virginia (continued)	• Such notification shall set forth the time and place of such spill or discharge, type or types and quantity or quantities of the material or materials therein, action or actions taken to stop such spill or discharge and to minimize the polluting effect thereof, the measure or measures taken or to be taken in order to prevent a recurrence of any such spill or discharge and such additional information as may be requested by the Division of Water Resources; • It shall be the responsibility of each industrial establishment or other entity discharging directly to a stream to have available insofar as practicable and reasonable the following information pertaining to those substances that are employed or handled in its operation in sufficiently large amounts as to constitute a hazard in case of an accidental spill and discharge into a public stream: (1) Potential toxicity in water to man, animals and aquatic life; (2) Details on analytical procedures for the quantitative estimation of such substances in water; (3) Suggestions on safeguards or other precautionary measures to nullify the toxic effects of a substance once it has gotten into a stream; • A written verification of such report shall be submitted upon request of the Division of Water Resources. The following measures for control of acid mine drainage are hereby adopted by the Water Resources Board: • Surface waters and ground waters shall be diverted where practicable to prevent the entry or reduce the flow of waters into and through workings.

(continued)

TABLE A-II-13. (continued)

Region and state	Applicable non-numerical standards and criteria
4. West Virginia (continued)	• Water that does gain entry to the workings shall be handled in a manner which will minimize the formation and discharge of acid mine drainage to streams. • Refuse from the mining and processing of coal shall be handled and disposed of in a manner which will minimize discharge of acid mine drainage therefrom to streams. Where acid-producing materials are encountered in the overburden in stripping operations, these materials shall be handled so as to prevent or minimize the production of acid mine drainage, taking into consideration the need for stream pollution prevention and all economic factors involved. • Discharge of acid mine drainage to streams shall be regulated insofar as practicable to equalize the flow of daily accumulations throughout a 24-hour period. • Upon discontinuance of operations of any mine, all practicable mine-closing measures, consistent with safety requirements, shall be employed to minimize the formation and discharge of acid mine drainage. • Under appropriate circumstances, consideration shall be given to the treatment of acid mine drainage by chemical or other means in order to mitigate its pollution properties.

REFERENCES

1. Cleland, J.G. and G.L. Kingsbury. Multimedia Environmental Goals for Environmental Assessment. Volume 1. EPA-600/7-77-136a. U.S. Environmental Protection Agency, Industrial Environmental Research Laboratory, Research Triangle Park, North Carolina. 1977.

2. Cornaby, B.W., D.A. Savitz, M.E. Stout, G.E. Pierce, and A.W. Rudolph. Development of Environmental Goals for Nonchemical and Nonpollution Factors in Fluidized-Bed Combustion. Draft Report Technical Directive 31 to EPA, IERL, RTP, N.C. Contract No. 68-02-2138 by Battelle Columbus Laboratories, 505 King Avenue, Columbus, Ohio 43201. 1977.

3. Bureau of National Affairs. 65 Specified Toxic Chemicals Listed. Env. Reporter, Current Development 8(40) 1509. 1978.

4. Cleland, J.G. and G.L. Kingsbury. Summary of Key Federal Regulations and Criteria for Multimedia Environmental Control. U.S. Environmental Protection Agency Contract No. 68-02-1325, Research Triangle Institute (RTI) Project No. 41U-893-75. Prepared for EPA/IERL by RTI, Research Triangle Park, NC. 1977.

5. Goldsmith, B.J. and J.R. Mahoney. Implications of the 1977 Clean Air Act Amendments for Stationary Sources. Environmental Science and Technology. 12(2):145. 1978.

6. Bureau of National Affairs. DOE Recommends Modifications in Proposal Clean-Air Area Rules. Environmental Reporter, Current Developments 8(41):1531. 1978.

7. ibid. Texas Submits First Application to Waive Offset Policy Requirements. Env. Reporter, Current Developments 8(23):857. 1977.

8. ibid. EPA Fugitive Dust Policy Focuses on Urban Emissions. Env. Reporter, Current Developments 8(17):664. 1977.

9. Barrett, B.R. Controlling the Entrance of Toxic Pollutants into U.S. Waters. Environmental Science and Technology 12(2):154. 1978.

APPENDIX III

RADIOACTIVITY

A-III RADIOACTIVITY

With the long-lived natural isotopes such as thorium-232, uranium-238, and uranium-235, a condition known as "radioactive or secular equilibrium" exists. This condition describes a steady state (and is hereafter referred to as such in this report) in which the amount of any member of the series does not change for a long period of time. For example, the amount of uranium-235 expected in 28,123 Mg of Illinois No. 6 coal (e.g., 45,000 grams total uranium expected multiplied by the relative abundance 0.72 percent or 324 grams) would decrease exactly one gram in 3.18×10^6 years. The calculated derivations given in the text of Chapter 3 should be applicable for this period of time, after which a correction of 0.3 percent will be necessary.

The time needed to reach the steady-state condition is determined by the longest half-lived daughter and is 5.0×10^5 years in the case of the decay of uranium-235 (the actinium series). In the case of the uranium-238, the time needed to reach steady state is 3.7×10^6 years and the time required for the thorium series to reach steady state is 211 years. Since the age of the Illinois No. 6 coal deposits is about 300×10^6 years, the assumption that the steady-state concentrations of these decay series have been reached is warranted.

Since steady-state concentrations exist, one can calculate the amount of the various isotopes that would be associated with 28,123 Mg coal, given the amount of uranium and thorium. It is interesting to note that the amount of uranium-234 estimated by this method is 2.4 grams, which compares favorably to the value of 2.6 grams estimated from natural abundance data for this isotope.

APPENDIX IV

ENVIRONMENTAL INFORMATION, WHITE COUNTY, ILLINOIS

TABLE A-IV-1. HISTORICAL STRUCTURES, MARKERS, TRAILS AND CENTENNIAL FARMS IN WHITE COUNTY, ILLINOIS

BURNT PRAIRIE				
WH-H-1	Morrison's Mill	East Edge of Burnt Prairie	1881	Grist Mill
CARMI				
WH-H-2	White County Courthouse	Main Street	1883	
WH-H-3	Robinson-Stewart House*	110 S. Main Cross Street	1814	Home of U.S. Senator
WH-H-4	Ratcliff Inn*	214 E. Main	1828	Stage Coach Inn
WH-H-5	Revolutionary War Memorial	Corner of Main and Main Cross	erected 1936	Memorial
WH-H-6	Civil War Memorial	Corner of Main and Main Cross		Civil War Cannon
WH-H-7	Carmi Public Library	201 Church Street	1912	Carnegie Library
WH-H-8	John M. Crebs House	311 West Main	1905	Banker
WH-H-9	Dr. Daniel Berry Home*	210 Stewart	1863	Army surgeon
WH-H-10	Pomeroy Home	305 West Main	1875	
WH-H-11	North Storms Home*	305 South Third	1872	Grain merchant
WH-H-12	Col. Everton Conger Home*	302 West Main	1871	Captor of John Wilkes Booth

(continued)

TABLE A-IV-1. (continued)

CARMI (continued)				
WH-H-13	Lincoln Speech Site Marker	NE corner Main & 4th	1840	Harrison campaign speech
WH-H-14	The old graveyard	Kerney and Main Cross		
CARMI VICINITY				
WH-H-15	James Logan House	SE of Carmi RR #5	1908	
ENFIELD				
WH-H-16	Southern Illinois Academy*	U.S. 45 in Enfield	1875	Alma Mater of Sen. William E. Boralt
GREYVILLE				
WH-H-17	Grey-Carey House*	119 N. Court	1885	Founder of Greyville
NEW HAVEN VICINITY				
WH-H-18	Old Stage Inn*	1 mile NW of New Haven		
NORRIS CITY VICINITY				
WH-H-19	Old Sharon Church*	N of Norris City	1864	Old Presbyterian Church

(continued)

TABLE A-IV-1. (continued)

NORRIS CITY VICINITY (continued)

WH-H-20	Clarence Pyle House*	2 miles SE of Norris City	Old Stage Coach Inn

HISTORICAL MARKERS

1. "Thy Wondrous Story Illinois" - Plywood - N side U.S. 460 - 4-1/2 miles W of Indiana state line near Crossville.

2. "Carmi, Illinois" - Plywood - S side of U.S. 460 - 5 miles W of Carmi
(3 signs) E side of Illinois 1 - south edge of Carmi
E side of Illinois 1 - 2 miles north of Carmi

3. "Big Prairie Church" - Cast metal - Blacktop road - SE of Carmi

4. "Carmi's Oldest House" - Cast metal - 100 South Main Cross Street - Carmi

5. "Col. Conger House" - Cast metal - 302 West Main - Carmi

6. "Flow Gently Sweet Afton" - Cast metal - 312 South 1st Street - Carmi

7. "Ratcliff Inn" - Cast metal - 206 East Main Street - Carmi

8. "The First Presbyterian Church in Illinois" - Cast metal - U.S. 45 - N of Norris City

9. "Liberty's Pioneer Mill (Old Morrison Mill)" - Cast metal - E edge of Burnt Prairie

10. "Southern Illinois College" - Cast metal - U.S. 45 - Enfield

MAJOR TRACES AND TRAILS

1. Shawneetown - Vincennes Trail

(continued)

TABLE A-IV-1. (continued)

CENTENNIAL FARMS

1. James & Offie Austin - R 1 - Norris City, Illinois
2. Ina Hollerback - R 5 - Carmi, Illinois
3. Roy Aud - R 1 - Norris City, Illinois
4. Paul Knight - R 1 - Omaha, Illinois
5. Noel Marlin - Herald, Illinois
6. Dayton Marlin - R 1 - Norris City, Illinois
7. Arthur Marlin - Box 408 - Norris City, Illinois
8. Marjorie Marlin - Box 116 - Norris City, Illinois
9. Bernard Marlin - Herald, Illinois
10. Sylvester Austin - Norris City, Illinois
11. Charles Smith - R 1 - Burnt Prairie, Illinois
12. Gale Williams - R 3 - Carmi, Illinois
13. Mr. & Mrs. Charles R. Long - R 1 - Crossville, Illinois
14. Morris & Ruth Harper West - R 2 - Norris City, Illinois
15. John M. Campbell, Jr. & John M. Campbell, Sr. - R 1 - Carmi, Illinois
16. Mrs. Myrtle Knight - Norris City, Illinois
17. Rolla H. Stocke - R 2 - Carmi, Illinois

(continued)

TABLE A-IV-1. (continued)

CENTENNIAL FARMS (continued)

18. Marion Mitchell McGinnis - RR - Norris City, Illinois

19. Oren E. Williams & Thelma R. Williams, Charles Williams & Wilma Williams - R 2 - Enfield, Illinois

20. Miss I.J. Dartt & Mrs. Marilyn Dartt Price - New Harmony, Indiana

21. Harriet Barnes Vaught - 210 Stewart Street - Carmi, Illinois

22. Thomas Miller Vaught - 210 Stewart Street - Carmi, Illinois

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*Structures of special merit and deserving of immediate attention.

Reference: Illinois Historic Landmarks Survey. Inventory of Historic Landmarks in White County. Illinois Department of Conservation, Springfield, Illinois, 1973.

TABLE A-IV-2. REPRESENTATIVE AQUATIC PLANTS FOUND OR LIKELY TO BE FOUND IN THE WABASH RIVER OR ITS TRIBUTARIES IN OR NEAR WHITE COUNTY

Common Name	Scientific Name	Found in the Wabash River	Found in its tributaries	Found in lakes and impoundments	Emergent^a	Reference^b
Columbia watermeal	Wolffia columbiana Karst.			*	-	C
Star duckweed	Lemna trisulca L.			*	-	C
Very tiny duckweed	Lemna perpusilla Torr.			*	-	C
Valdivia duckweed	Lemna valdiviana Phil.			*	-	C
Smaller duckweed	Lemna minor L.			*	-	C
Giant duckweed	Spirodela polyrhiza L. Schleidon			*	-	C
Common cattail	Typha latifolia L.	*	*	+	+	C
Narrowleaf cattail	Typha angustifolia L.			*	+	C
Giant bur-reed	Sparganium eurycarpum Engelm			*	+	C
Lean sedge	Cyperus strigosus L.			*		C
American bulrush	Scirpus americanus Pers.	*	*	*	+	C
Slendor spikerush	Eleocharis acicularis (L)R.&S.			*		C
Blunt spikerush	Eleocharis obtussa (Willd)Schult.			*		C
Marsh mermaid weed	Proserpinaca palustris L.			*	+	C
Water-starwort	Callitriche heterophylla Pursh			*	-	C
Water hyssop	Bacopa rotundifolia (Michx)Wettst.			*	+	C
American water-willow	Dianthera americana L.			*		C
Common bladderwort	Utricularia vulgaris L.			*	-	C
Humped bladderwort	Utricularia gibba L.			*		C
Common arrowhead	Sagittaria latifola L.			*	+	C
Heart shaped water plantan	Alisma subcordatum Rafinesque			*	+	C
Beaked burhead	Echinodorus rostatus (Nutt)Engelm.			*	+	C
Brittle naiad	Najas minor All.			*	-	C
Bushy naiad	Najas gracillima (A.Br) Magnus			*	-	C
Slendor naiad	Najas flexilis (Willd.) R&S			*	-	C
Southern naiad	Najas guadalupensis (Spreng)Magnus		*	*	-	C
American pondweed	Potamogeton nodosus Poir.			*	-	C
Variable pondweed	Potamogeton gramineus L.	*	*		-	C
Illinois pondweed	Potamogeton illinoensis Morong			*	-	C
Ribbonleaf pondweed	Potamogeton epihydrus Rafinesque			*	-	C
Floating leaf pondweed	Potamogeton natans L.			*	-	C
Waterthread pondweed	Potamogeton diversifolius Rafinesque			*	-	C
Leafy pondweed	Potamogeton foliosus Rafinesque			*	-	C
Small pondweed	Potamogeton pusillus L.			*	-	C
Pickerel weed	Pontederia cordata L.		*	*	+	C
American elodea	Elodea canadensis Michx.			*	-	C
Arrow arum	Peltandra virginica (L.)Kunth			*	+	C
Sweet flag	Acorus calamus L.			*		C
Dotted watermeal	Wolffia punctata Griseb.			*	-	C
Papillary watermeal	Wolffia papulifera Thompson			*	-	C
Duckweed	Lemna sp.	+			-	A,D
Sago pondweed	Potamogeton pectinatus L.			+	-	B,C
Primrose	Jussiaeo sp.			+	±	C
Coontail	Ceratophyllum demersum L.			+	-	B,C
Stoneworts	Nitella sp.				-	B,C
Stoneworts	Chara sp.				-	C
Slendor riccia	Riccia fluitans L.			*	-	C
Purple-fringed riccia	Ricciocarpus natans (L)Corda			*	-	C
Blackfooted guillwort	Isoetes melanopoda Gay & Dur				-	C
Pepperwort	Marsilea quadrifolia L.			*	±	C

(continued)

TABLE A-IV-2. (continued)

Common Name	Scientific Name	Found in the Wabash River	Found in its tributaries	Found in lakes and impoundments	Emergent[a]	Reference[b]
Rigid white water buttercup	Ranunculus longirostris Godr.			*	-	C
Water shield	Brasenia schreberi Gmel.				-	C
Spatterdock	Nuphar advena Ait.			*	-	C
White water lily	Nymphaea tuberosa Paine			*	±	C
American lotus	Nelumbo lutea (Willd.) Pers.			*	±	C
Prickly coontail	Ceratophyllum echinatum Gray			*	-	C
Lake cress	Armoracia aquatica (Eat.)Wieg.			*	±	C
True water cress	Rorippa nasturtium-aquaticum(L)Hayek				-	C
Water smartweed	Polygonum fluitans Eaton			*	±	C
Dutch stonecrop	Penthorum sedoides L.			*	±	C
Water purslane	Peplis diandra Nutt.			*	±	C
False loosestrife	Ludwigia palustris (L.)Ell.			*	±	C
Broadleaf water milfoil	Myriophyllum heterophyllum Michx.			*	±	C
Whorled water milfoil	Myriophyllum verticillatum L.			*	±	C

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[*] The habitat of this species indicates that it is likely to be found in this location.

[a] A plus-minus ("±") sign in this column indicates that this plant is sometimes emergent.

[b] Reference A: U.S. Department of Agriculture, Rural Electrification Administration. Merom Generating Station and Associated Transmission -- Final Environmental Impact Statement, USDA-REA-ES(ADM)-76-10-F. U.S. Department of Agriculture, Washington, DC, 1977.

Reference C: Winterringer, G.S. and A.C. Lopinot. Aquatic Plants of Illinois. Illinois State Museum Popular Science Series Vol. VI. Published Jointly by the Department of Registration and Education, Illinois State Museum Division and the Department of Conservation, Division of Fisheries, Illinois State Museum, Springfield, Illinois, 1977.

Reference D: Beck, R.W., and Associates. Environmental Analysis Merom Generating Station for Hoosier Energy Division of Indiana Statewide R.E.C., Inc., 1976.

TABLE A-IV-3. TERRESTRIAL PLANTS WHICH MAY BE FOUND IN WHITE COUNTY, ILLINOIS

Scientific Name	Common Name	Reference*
Acalypha rhomboidea	Three seeded mercury	E
Acalypha virginica		E
Acer negundo L.	Boxelder (Ash-leaved maple)	B,C,D,E,A
Acer nigrum Michx. f.	Black maple	B,A
Acer rubrum L.	Red maple	B,E,A
Acer saccharinum L.	Silver maple	B,E,A
Acer saccharum Marsh.	Sugar maple	B,C,A
Actinomeris alternifolia	Wingstem	E
Aesculus glabra Willd.	Ohio buckeye	B,A
Agastache nepetoides	Horsemint	E
Agrostis hyemalis	Tickle grass	E
Ailanthus altissima	Tree-of-Heaven	E
Allium canadense	Wild onion	E
Ambrosia artemisiifolia	Common ragweed	E
Ambrosia trifida	Giant ragweed	E
Amelanchier sp.	Serviceberry	B,A
Ammannia coccinea		E
Anagallis arvensis	Scarlet pimpernel	E
Andropogon virginicus	Broomsedge	E
Arabis laevigata	Smooth rockcress	E
Aralia spinosa	Devils-walking stick	B
Arctium minus	Common burdock	E

(continued)

TABLE A-IV-3. (continued)

Scientific Name	Common Name	Reference
Artemisia annua	Annual Wormwood	E
Aruncus dioicus	Goat's beard	E
Ascyrum hypericoides	St. Andrew's cross	E
Asimina triloba (L.) Dunal	Pawpaw	B,D,E,A
Asplenium platyneuron (L.) Oakes	Ebony spleenwort	A
Aster ericoides		E
Aster lateriflorus		E
Aster ontarionis		E
Aster pilosus		E
Aster simplex		E
Barbarea vulgaris	Common wintercress	E
Betula alleghaniensis	Yellow birch	E
Betula nigra	River birch	E
Bidens bipinnata	Spanish needles	E
Bidens frondosa	Beggar ticks	E
Bidens polylepis		E
Bidens vulgata		E
Blephilia hirsuta	Wood mint	E
Bochmeria cylindrica	False nettle	E
Bromus racemosus		E
Campsis radicans (L.) Seem	Trumpet-creeper	A
Cardamine bulbosa	Spring cress	E

(continued)

TABLE A-IV-3. (continued)

Scientific Name	Common Name	Reference
Carex abscondita		E
Carex bushii		E
Carex cephalophora		E
Carex cristatella		E
Carex grayii		E
Carex hitchcockiana		E
Carex jamesii		E
Carex laxiflora		E
Carex louisianica		E
Carex muehlenbergii		E
Carex muskingumensis		E
Carex nigromarginata		E
Carex normalis		E
Carex oligocarpa		E
Carex rosea		E
Carex scoparia		E
Carex shortiana		E
Carex sparganioides		E
Carex squarrosa		E
Carex tetanica		E
Carex umbellata		E
Carpinus caroliniana Walt.	American hornbeam (Blue beech)	B,E,A

(continued)

TABLE A-IV-3. (continued)

Scientific Name	Common Name	Reference
Carya cordiformis (Wangenh.) K. Koch	Bitternut hickory	B,C,E,A
Carya glabra	Pignut hickory	B,E
Carya illinoensis	Pecan	B,E
Carya laciniosa	Shellbark hickory	B,E
Carya ovalus	Small-fruited hickory	E
Carya ovata (Mill.) K. Koch	Shagbark hickory	B,C,D,A
Carya tomentosa Nutt.	Mockernut hickory	B,A
Catalpa speciosa Warder	Northern catalpa	B,A
Celtis laevigata	Sugarberry	E
Celtis occidentalis L.	Hackberry	B,C,A
Cephalanthus occidentalis	Common buttonbush	B
Cercis canadensis L.	Eastern redbud	B,E,A
Chaerophyllum tainturieri		E
Chelone obliqua	Turtlehead	E
Cinna arundinacea	Wood reedgrass	E
Circaea quadrisulcata	Enchanter's nightshade	E
Claytonia virginica	Spring beauty	E
Corallorhiza wisteriana	Wister's coral-root orchid	E
Corydalis flavula	Yellow fumewort	E
Cornus alternifolia L.f.	Alternate-leaf dogwood	B,A
Cornus drummondii	Roughleaf dogwood	B,E
Cornus florida	Flowering dogwood	B,C,D,E

(continued)

TABLE A-IV-3. (continued)

Scientific Name	Common Name	Reference
Cornus obliqua Raf.	Silky dogwood	A
Corylus americana	Hazelnut	A,E
Crataegus crus-galli	Cockspurthorn	E
Crataegus mollis	Hawthorn	B,A
Cryptotaenia canadensis	Honewort	E
Cuphea petiolata	Waxweed	E
Danthonia spicata	Poverty grass	E
Delphinium tricorne	Wild larkspur	E
Dentaria laciniata	Toothwort	E
Desmodium glabellum	Tick trefoil	E
Desmodium nudiflorum		E
Desmodium pauciflorum		E
Dicentra cucullaria	Dutchman's breeches	E
Digitaria sanguinalis	Crabgrass	E
Diodia teres	Rough buttonweed	E
Diospyros virginiana	Persimmon	E
Dirca palustris L.	Leatherwood	A
Echinochloa crusgalli	Barnyard grass	E
Echinochloa walteri		E
Eclipta alba	Yerba-de-tago	E
Eleocharis obtusa	Spike rush	E
Elephantopus carolinianus	Elephant's foot	E
Elymus canadensis	Nodding wild rye	E

(continued)

TABLE A-IV-3. (continued)

Scientific Name	Common Name	Reference
Elymus virginicus		E
Erigenia bulbosa	Harbinger of spring	E
Erigeron annuus	Daisy fleabane	E
Erigeron canadensis	Horseweed	E
Erigeron philadelphicus		E
Euonymus atropurpureus	Eastern wahoo	B,E
Eupatorium coelestinum	Mistflower	E
Eupatorium purpureum	Joe Pye weed	E
Eupatorium rugosum	White snakeroot	E
Eupatorium serotinum	Late boneset	E
Euphorbia humistrata		E
Euphorbia maculata	Nodding spurge	E
Euphorbia supina	Milk spurge	E
Erythronium albidum	White trout lily	E
Fagus grandifolia Ehrh.	American beech	B,C,E,A
Festuca obtusa		E
Fraxinus americana L.	White ash	B,A,E
Fraxinus nigra Marsh.	Black ash	A
Fraxinus pennsylvanica	Red ash	E
Fraxinus pennsylvanica var. subintegerrima	Green ash	E
Fraxinus quadrangulata	Blue ash	B
Galium aparine	Goosegrass	E
Galium circaezans	Wild licorice	E

(continued)

TABLE A-IV-3. (continued)

Scientific Name	Common Name	Reference
Galium concinnum	Bedstraw	E
Galium obtusum		E
Galium triflorum	Sweet-scented bedstraw	E
Geranium carolinianum	Carolina cranesbill	E
Gerardia flava	False foxglove	E
Gerardia tenuifolia		E
Geum canadense	White avens	E
Geum vernum	Spring avens	E
Geum virginianum		E
Gledista triacanthos L.	Honeylocust	B,E,A
Gratiola neglecta	Hedge hyssop	E
Gymnocladus dioicus (L.) K. Koch	Kentucky coffeetree	B,E,A
Hamamelis virginiana	Witch-hazel	E
Hedeoma pulegioides	Pennyroyal	E
Hordeum pusillum	Small wild barley	E
Houstonia purpurea		E
Hydrastis canadensis	Goldenseal	E
Hydrophyllum appendiculatum	Waterleaf	E
Hypericum punctatum	Spotted St. John's-wort	E
Hypericum tubulosum Var. Walteri		E
Juglans cinerea L.	Butternut	B,A
Juglans nigra L.	Black walnut	B,C,A

(Continued)

TABLE A-IV-3. (continued)

Scientific Name	Common Name	Reference
Juncus tenuis	Rush	E
Juniperus virginiana L.	Eastern redcedar	A
Lactuca canadensis	Common wild lettuce	E
Lactuca floridana	Blue wild lettuce	E
Laportea canadensis	Wood nettle	E
Leersia virginica	White grass	E
Lespedeza hirta	Bush clover	E
Lespedeza violacea		E
Lespedeza virginica		E
Lindera benzoin (L.) Blume	Spicebush	A,E
Liparis lilifolia	Twayblade orchid	E
Liquidambar styraciflua	Sweetgum	B,C,E
Liriodendron tulipifera L.	Yellow-poplar	B,E,A
Luzula bulbosa	Woodrush	E
Lycopus rubellus	Water horehound	E
Lysimachia lanceolata	Narrowleaved loosestrife	E
Lysimachia nummularia	Moneywort	E
Ilex decidua	Deciduous holly	E
Iodanthus pinnatifidus	Purple rocket	E
Maclura pomifera (Raf.) Schneid.	Osage-orange	A
Magnolia acuminata	Cucumber tree	B
Malus coronaria	Sweet crab apple	B

(continued)

TABLE A-IV-3. (continued)

Scientific Name	Common Name	Reference
Mimulus alatus	Monkey flower	E
Morus alba	White mulberry	E
Morus rubra	Red mulberry	B,E
Muhlenbergia frondosa		E
Myosurus minimus	Mousetail	E
Nyssa sylvatica	Black tupelo	B,E
Oenothera biennis	Evening primrose	E
Osmorhiza claytoni	Sweet cicely	E
Ostrya virginiana (Mill.) K. Koch	Eastern hophornbeam	A,B,E
Oxalis europaea	Common wood sorrel	E
Oxalis stricta	Yellow wood sorrel	E
Oxalis violacea	Violet wood sorrel	E
Panicum capillare		E
Panicum dichotomiflorum		E
Panicum lanuginosum var. fasciculatum		E
Panicum nitidum		E
Panicum oligosanthes		E
Parietaria pensylvanica	Pellitory	E
Paspalum pubiflorum		E
Penstemon digitalis	Beard tongue	E
Phleum pratense	Timothy	E
Phlox divaricata	Blue phlox	E

(continued)

TABLE A-IV-3. (continued)

Scientific Name	Common Name	Reference
Phlox paniculata	Panicled phlox	E
Phryma leptostachya	Lopseed	E
Physalis pubescens	Groundcherry	E
Physalis subglabrata		E
Physocarpus opulifolius (L.) Maxim.	Ninebark	A
Phytolacca americana	Pokeweed	E
Pilea pumila	Clearweed	E
Pinus echinata Mill.	Shortleaf pine	A
Plantago rugelii	Common plantain	E
Platanus occidentalis L.	American sycamore	B,A
Poa compressa	Canada bluegrass	E
Poa pratensis	Kentucky bluegrass	E
Poa sylvestris		E
Polemonium reptans	Jacob's ladder	E
Polygonatum canaliculatum	Solomon's seal	E
Polygonum hydropiper	Common smartweed	E
Polygonum pensylvanicum	Smartweed	E
Polygonum punctatum	Water smartweed	E
Polystichum acrostichoides (Michx.) Schott	Christmas fern	A
Populus deltoides Bartr.	Eastern cottonwood	B,A,E
Populus grandidentata	Bigtooth aspen	B
Populus heterophylla	Swamp cottonwood	B
Prenanthes altissima	Rattlesnake root	E

(continued)

TABLE A-IV-3. (continued)

Scientific Name	Common Name	Reference
Prunella vulgaris	Selfheal	E
Prunus americana	Wild american plum	B,E
Prunus serotina Ehrh.	Wild black cherry	B,A,E
Prunus virginiana L.	Common chokecherry	B,A
Pycnanthemum flexuosum	Mountain mint	E
Pyrus angustifolia	Wild crab-apple	E
Quercus alba L.	White oak	B,C,D,E,A
Quercus bicolor	Swamp white oak	D,B,E
Quercus falcata var. pagodaefolia	Cherry-bark oak	E
Quercus imbricaria	Shingle oak	E,B
Quercus laurifold	Laurel oak	D
Quercus lyrata	Overcup oak	E
Quercus macrocarpa	Burr oak	A,E
Quercus marilandica	Blackjack oak	B
Quercus michauxii	Basket oak (Swamp Chestnut Oak)	E,B
Quercus muehlenbergii	Chinkapin oak	E,B,C
Quercus palustris Muenchh.	Pin oak	E,B,A
Quercus prinus	Chestnut oak	B
Quercus rubra L.	Northern red oak	E,A,B,C
Quercus shumardii	Shumard oak	B,E
Quercus stellata	Post oak	E
Quercus velutina Lam.	Black oak	B,E,A

(continued)

TABLE A-IV-3. (continued)

Scientific Name	Common Name	Reference
Ranunculus abortivus	Kidney-leaf buttercup	E
Ranunculus recurvatus		E
Ranunculus septentrionalis	Swamp buttercup	E
Rhus copallina	Shining sumac	B
Rhus glabra	Smooth sumac	E
Rhus radicans L.	Poison ivy	A,E
Rhus typhina L.	Staghorn sumac	B,A
Robinia pseudoacacia L.	Black locust	C,A
Rosa multiflora Thunb.	Multiflora rose	A
Rosa setigera	Climbing rose	E
Rotala ramosior	Tooth cup	E
Rubus allegheniensis	Allegheny blackberry	A
Rubus spp.	Raspberry	A
Rudbeckia laciniata	Golden glow	E
Rudbeckia subtomentosa	Fragrant coneflower	E
Rudbeckia triloba	Brown-eyed Susan	E
Rumex altissimus	Pale dock	E
Rumex obtusifolius	Bitter dock	F
Sambucus canadensis L.	Common (American) elder	B,A,E
Salix interior	Sandbar willow	B
Salix lucida	Shining willow	E
Salix nigra Marsh.	Black willow	E,B,C,A

(continued)

TABLE A-IV 3. (continued)

Scientific Name	Common Name	Reference
Samolus parviflorus	Brookweed	E
Sanguinaria canadensis	Bloodroot	E
Sanicula canadensis	Black snakeroot	E
Sanicula gregaria		E
Sassafras albidum (Nutt.) Nees	Sassafras	B,E,A
Saururus cernuus	Lizard's tail	E
Scirpus atrovirens	Bulrush	E
Scirpus lineatus		E
Scrophularia marilandica	Figwort	E
Scutellaria lateriflora	Skullcap	E
Scutellaria nervosa		E
Scutellaria ovata		E
Sedum ternatum	Three-leaved stonecrop	E
Senecio aureus	Golden ragwort	E
Senecio glabellus	Butterweed	E
Setaria viridis	Green foxtail	E
Seymeria macrophylla	Mullein foxglove	E
Smilacina racemosa	False Solomon's seal	E
Smilax rotundifolia L.	Common greenbriar	A
Solidago altissima	Tall goldenrod	E
Solidago caesia	Blue-stemmed goldenrod	E
Solidago gigantea	Late goldenrod	E

(continued)

TABLE A-IV 3. (continued)

Scientific Name	Common Name	Reference
Solidago ulmifolia	Elm-leaved goldenrod	E
Spermacoce glabra	Smooth buttonweed	E
Sphenopholis intermedia		E
Sphenopholis nitida		E
Stachys tenifolia	Common hedgenettle	E
Staphylea trifolia L.	Bladdernut	A
Symhoricarpos orbiculatus	Coralberry	E
Taraxacum officinale	Dandelion	E
Taxodium distichum	Baldcypress	B
Teucrium canadense	Wood sage	E
Thalictrum dioicum	Early meadowrue	E
Tilia americana L.	American basswood	B,A,E
Tovara virginiana	Virginia knotweed	E
Trillium flexipes	White trillium	E
Trillium recurvatum	Resurved wakerobin	E
Ulmus americana L.	American elm	B,D,A,F
Ulmus rubra Muhl.	Slippery elm	B,A,E
Ulmus thomasii Sarg.	Rock elm	B,A
Vernonia altissima	Ironweed	E
Vernonia missurica		E
Verbascum blattaria	Moth mullein	E
Verbascum thapsus	Common mullein	F
Verbena urticifolia	White vervain	E

(continued)

TABLE A-IV-3. (continued)

Scientific Name	Common Name	Reference
Virburnum lentago L.	Nannyberry	B,A
Virburnum prunifolium	Blackhaw	B,A
Viola kitaibeliana var. rafinesquii	Field pansy	E
Viola pipilionacea	Blue violet	E
Viola pensylvanica	Smooth yellow violet	E
Vitis sp.	Grape	B,A
Xanthium italicum	Cocklebur	E
Xanthoxylum americanum	Common prickly-ash	B

*Reference A: U.S. Department of Agriculture, Rural Electrification Administration. Merom Generating Station and Associated Transmission -- Final Environmental Impact Statement. USDA-REA-ES(ADM)-76-10-F. U.S. Department of Agriculture, Washington, DC, 1977.

Reference B: Brockman, C.F. Trees of North America. Golden Press, New York, 1968.

Reference C: Page, L.M. Personal Communication. Illinois Natural History Survey, Natural Resources Building, Urbana, Illinois 61801, 1977.

Reference D: Beck, R.W. and Associates. Environmental Analysis Merom Generating Station for Hoosier Energy Division of Indiana Statewide R.E.C., Inc., 1976.

Reference E: Ashby, W.C. and J.E. Ozmet. Plant Species of Beall's Woods, Wabash County, Illinois, Transactions, Illinois State Academy of Science, 60(2):174-183, 1967.

TABLE A-IV-4. PHYTOPLANKTON SPECIES IN SEVERAL TRIBUTARIES OF THE WABASH RIVER IN AND AROUND WHITE COUNTY, ILLINOIS*

Common Name	Scientific Name	Found in the Wabash River	Found in its Tributaries	Found in Lakes and Impoundments	Reference
Blue-green algae					
(example):		+	+		A,C
	Aphanizomenon sp.		+		B
Green algae					
(examples):		+	+		A,C
	Actinastrum sp.		+		B
	Ankistrodesmus sp.		+		B
	Chlorella sp.		+		B
	Closteridium		+		B
	Crucigenaia sp.		+		B
	Crucigemaia sp.		+		B
	Oocystis sp.		+		B
	Pediastrum sp.		+		B
	Scenedesmus sp.		+		B
	Ulothrix sp.		+		B
Diatoms					
(examples):		+	+		A,C
	Asterionella sp.		+		B
	Caloneis sp.		+		B
	Cymbella sp.		+		B
	Cyclotella sp.		+		B
	Diatoma sp.		+		B
	Fragilaria sp.		+		B
	Gomphonema sp.		+		B
	Gyrosigma sp.		+		B
	Melosira sp.		+		B
	Navicula sp.		+		B
	Neidium sp.		+		B
	Nitschia sp.		+		B
	Pleurosigma sp.		+		B
	Stephanodiscus sp.		+		B
	Surirella sp.		+		B
	Synedra sp.		+		B
	Tabellaria sp.		+		B
Flagellates					
(examples):					
	Chlamydomonas sp.		+		B
	Euglena sp.		+		B
	Phacus sp.		+		B
Rotifers					
(examples):		+	+		C
	Platyids sp.	+			A
	Keratella sp.	+			A
	Branchious sp.	+			A
Aquatic fungi					
Crustacea copepoda		+	+		A,C
Nauplii					
Copepodids		+	+		C
Cladocera		+	+		C
Periphyton-metazoa		+	+		C
Fecal coliform		+	+		C
Golden brown flagellate		+	+		C
algae			+		C
Periphyton-protozoa		+	+		C

*Reference A: U.S. Department of Agriculture, Rural Electrification Administration. Merom Generating Station and Associated Transmission - Final Environmental Impact Statement. USDA-REA-ES (ADM)-76-10-F, U.S. Department of Agriculture. Washington, D.C. 1977.

Reference C: Lin, S.D., R.L. Evans, and D.B. Beuscher. Concentration and Genera of Algae in Selected Illinois Streams, 1971-1975. Report of Investigation 80, Illinois State Water Survey, Urbana, IL. 1975.

Reference D: Beck, R.W. and Associates. Environmental Analysis Merom Generating Station for Hoosier Energy Division of Indiana Statewide R.E.C., Inc. 1976.

TABLE A-IV-5. DISTRIBUTION OF PHYTOPLANKTON POPULATION IN SEVERAL TRIBUTARIES TO THE WABASH RIVER IN AND AROUND WHITE COUNTY

		2-Year Average (%)				Maximum For Any One Sample (%)[a]			Algal Density					Diversity Index				Algal Density Occurrence (% of Time)		
Tributary-Location	Number of Samples	Bluegreen	Green	Diatom	Flagellate	Bluegreen	Green	Flagellate	Arithmetic Mean	Geometric Mean	Arithmetic Unbiased Standard Deviation	Geometric Standard Deviation	Range	Arithmetic Mean	Geometric Mean	Arithmetic Unbiased Standard Deviation	Range	500	500-2000	2001-5000
Embarras River near Camargo	23	0.8	20.1	74.3	4.8	16.7	63.6	71.5	2100.	0.	1200.	N/A[c]	N.D.[d]-4700	1.32	0.00	0.68	0.0-2.68	8.3	37.5	54.2
Little Wabash River near Effingham	17	0.0	21.2	71.6	7.2	0.0	100.	57.2	1800.	0.	1200.	N/A	N.D.-4900	1.29	0.00	0.77	0.0-2.53	11.8	52.9	35.3
Little Wabash below Clay City	23	0.0	15.7	79.4	4.9	0.0	100.	45.5	1600.	1400.	730.	1.91	160-3000	1.20[b]	0.00	0.59	0.0-2.23	4.3	60.9	34.8
Raccoon Creek near Rinard	14	3.3	31.6	52.8	12.3	33.3	90.0	60.0	1720.	1300.	1300.	2.54	160-4900	1.30	0.00	0.58	0.0-1.92	14.3	50.0	35.7
Elm River at Enterprise	10	4.6	36.8	51.1	7.5	46.3	87.5	42.9	2000.	1700.	1600.	1.73	1100-6400	1.48	1.44	0.34	0.97-1.94	80.0	10.0	10.0
Skillet Fork at Wayne City	23	0.0	24.8	69.0	6.2	0.0	72.7	75.0	1800.	1500.	1200.	2.13	160-4900	1.24	0.00	0.50	0.0-1.91	4.5	58.6	36.9
Little Wabash River at Carmi	23	0.0	22.6	72.8	4.6	0.0	100.	37.5	1700.	0.	900.	N/A	N.D.-4200	1.34[b]	0.00	0.52	0.0-1.85	8.7	56.5	34.8

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[a] Maximum value for diatoms reached 100% for all stations for at least one sample.

[b] The diversity index appeared to undergo a significant decrease (p less than 0.05) from an arithmetic mean of 1.58 for the period November 1971 - September 1972 to an arithmetic mean of 1.12 for the period October 1972 to September 1973 for the Little Wabash River at Carmi. A similar decrease (p less than 0.05) was observed for the Little Wabash River below Clay City (1.45 to 0.97). No other trends in the data were noted (p greater than 0.1).

[c] N/A means not applicable.

[d] N.D. means none detected.

TABLE A-IV-6. REPRESENTATIVE AQUATIC MACROINVERTEBRATES, WITH THE EXCEPTION OF CLAMS AND MUSSELS, PRESENT IN THE WABASH RIVER OR ITS TRIBUTARIES IN OR NEAR WHITE COUNTY, ILLINOIS

Common Name	Scientific Name	Found in the Wabash River	Found in its tributaries	Tolerant to high organic load	Tolerant to low dissolved oxygen	Tolerant to metals	Tolerant to pesticides	Reference[a]
Segmented aquatic worms (Family: Tubificidae)	Limnodrilus hoffmeisteri (Claparede 1862)	+	+	+	+	+	+	C
	Limnodrilus claparedeianus (Ratzel 1868)	+	+	+	-	+	+	C
	Peloscolex multisetosus (Smith 1900)		+	+	+	-	-	C
	Peloscolex variegatus (Leidy 1851)	+	+	+	+	-	-	C
	Branchiura sowerbyi (Beddard 1892)		+	-	-	-	-	C
	Tubifex tubifex (Muller 1774)	+	+	+	+	-	-	C
(Family: Naididae)	Nais communis (Piguet 1906)		+	+	+			C
	Nais simplex (Piguet 1906)		+	+	+			C
	Dero obtusa (d'Udekem)		+	+	+			C
	Stylaria fossularis (Leidy 1852)		+	+	+			C
Crustacea		+	+					D
Crayfish			+					E
	Chironomus		+					F
Waterbugs	Corixa sp.		+					F
Leaches	Piscicolaria reducta		+					F
Mayflies	Ephemeroptera spp.	+	+					A,D,F
Caddisflies	Trichoptera spp.	+	+					A,D,F
Flies, mosquitoes	Diptera spp.	+	+					A,D,F
Beetles	Coleoptera spp.	+						A
Stoneflies	Plecoptera spp.	+						A
Moss animals	Bryozoa spp.	+						A
Dragonflies	Odonata spp.	+	+					A,F
Dobsonflies	Megaloptera spp.	+						A
Segmented worms	Annelida spp.	+						A
Aquatic worms	Oligochaeta spp.	+	+					A,D
Fairy shrimp, water fleas	Crustacea	+						A

[a] Reference A: U.S. Department of Agriculture, Rural Electrification Administration. Merom Generating Station and Associated Transmission -- Final Environmental Impact Statement. USDA-REA-ES(ADM)-76-10-F. U.S. Department of Agriculture, Washington, D.C., 1977.

Reference B: Fisher, R.E. and W.P. Brown. White County Surface Water Resources. Illinois Department of Conservation, Division of Fisheries Publication, 1971.

Reference C: Whitney, L.S., Professor of Zoology, Personal Communication, Division of Life Sciences, Eastern Illinois University, Charleston, Illinois, 1978.

Reference D: Parmalee, P.W. The Fresh-Water Mussels of Illinois, Popular Science Survey, Vol. VIII, Printed by Authority of the State of Illinois, Springfield, Illinois, 1967.

Reference E: Townsend, L.E. Personal communication. U.S. Environmental Protection Agency, Central District Office, 536 S. Clarck Street, Chicago, Illinois 60606. 1978.

Reference F: Page, L.M. and P.W. Smith. The Life History of the Dusky Darter, Percina sciera in the Embarras River, Illinois. Illinois Natural History Survey, Biological Notes No. 69, State of Illinois, Department of Registration and Education, Natural History Survey Division, Urbana, Illinois, September 1970.

TABLE A-IV-7. CLAMS AND MUSSELS WHICH MAY BE OBSERVED IN THE WABASH RIVER OR ITS TRIBUTARIES IN OR NEAR WHITE COUNTY, ILLINOIS

Common Name	Scientific Name	Commercially Valuable	Found in the Wabash River	Found in Its Tributaries	Found in Lakes & Impoundments	Common[a]	References[b]
yellow sand shell	*Lampsilis anodontoides* (Lea)	+	+	+		+	B,D,G
three ridge	*Amblema costata* Rafinesque	+	+	+		+	B,D,G
maple leaf	*Quadrula quadrula* Rafinesque	+	+	+	*	+	B,D,G
pig toe	*Fusconaia undata*	+	+	+			B,D,G
monkey face	*Quadrula metanevra* (Rafinesque)	+	+	+		=	B,D,G
pimple back	*Quadrula pustulosa* (Lea)	+	+	+		+	B,D,G
butterfly	*Plagiola lineolata* (Rafinesque)	+	+				B
washboard	*Megalonaias gigantea* (Barnes)	+	+	+		?	B,D,G
buckhorn; pistol							B,D,G
grip	*Tritogonia verrucosa* (Barnes)	+	+	+		+	B,D,G
hickory nut	*Obovaria olivaria* (Rafinesque)	+	+			+	B,D
warty back	*Quadrula nodulata* (Rafinesque)	+	+	+			B,D,G
bullhead; sheepnose	*Plethobasus cyphyus* (Rafinesque)	−	+			=	B,D,G
three horned warty							D
back	*Obliquaria reflexa* Rafinesque	−	+	+		?	D
spectacle-case	*Cumberlandia monodonta* (Say)		+				D,C
blue-point	*Amblema peruviana* (Lamarck)		+				D
Purple warty back	*Cyclonaias tuberculata* Rafinesque	−	+	+		=	D,G
spike, lady-finger	*Elliptio dilatatus* (Rafinesque)		+	+			D,G
elephant's ear	*Elliptio crassidens* (Lamarck)	−	?	+		+	D
Wabash pig-toe	*Fusconaia flava* (Rafinesque)			+			D,G
	Pleurobema cordatum (Rafinesque)	−	+	+		=	D
rabbit's foot	*Quadrula cylindrica* (Say)		+				D
pond-horn	*Uniomerus tetralasmus* (Say)		+		*		D,G
floater	*Anadonta grandis* (Say)	−	+		*	=	D
paper pond shell	*Anadonta imbecillis* (Say)	−	+		*		D
rock pocketbook	*Arcidens confragosus* (Say)		+	+	*		D,C
white heel-splitter	*Lasmigona complanata* (Barnes)	−	+	+	*	+	D,G
fluted shell	*Lasmigona costata* (Rafinesque)	−	+	+		=	D,G
squaw foot	*Strophitus rugosus* (Swainson)	−	+	+		?	D,B,G
mucket	*Antinonaias carinata* (Barnes)	+	+	+		+	D
liliput shell	*Carunculina parva* (Barnes)		+	+	*		D
	Carunculina glans (Lea)		+	+			D,G
fan-shell	*Cyprogenia irrorata* (Lea)	−	+			=	D
	Dysnomia perplexa (Lea)		+				D
slough sand shell	*Lampsilis fallaciosa* (Rafinesque)		+	+			D
	Lampsilis orbiculata (Hildreth)		+?				D
fat mucket	*Lampsilis siliquoidea* (Barnes)	+	+	+			D,G
pocketbook	*Lampsilis ovata ventri*[illegible]	−	+	+		+	D,G
fragile paper shell	*Leptodea fragilis* (Rafinesque)	−	+	+		+	D,G
pink paper shell	*Leptodea laevissima* (Lea)	−	+	+	*	=	D,G
black sand shell	*Ligumia recta* (Lamark)		+	+			D
pond mussel	*Ligumia subrostrata* (Say)				*		D
	Obovaria subrotunda (Rafinesque)	−	+	+		=	D,G
pink heel-splitter	*Proptera alata* (Say)	−	+	+		+	D,G
fat pocketbook	*Proptera capax* (Green)		+				D
kidney-shell	*Ptychobranchus fasciolaris* (Rafinesque)		+				D
fawn's foot	*Truncilla donaciformis* (Lea)		+	+			D
deer-toe	*Truncilla truncata* (Rafinesque)	−	+	+	*	=	D,G
	Fusconaia subrotunda (Lea)		+?				D
	Lastena lata (Rafinesque)		+?				D
	Plethobasus cicatricosus (Say)		+?				D
	Plethobasus cooperianus (Lea)		+?				D
	Pleurobema clava (Lamark)		+?				D
	Simpsoniconcha ambigua (Say)		+?				D
	Dysnomia foliata Hildreth		+?				D
	Dysnomia sulcata (Lea)		+?				D
	Dysnomia sampsoni (Lea)		+?				D
	Leptodea leptodon (Rafinesque)		+?				D
	Villosa (=Micromyo) fabalis (Lea)		+?				D
	Obovaria retusa (Lamarck)		+?				D
Asiatic clam							
(introduced)	*Corbicula* cf. *manillensis*		+				D

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* The habitat of this species indicates that it is likely to be found in this location.

[a] A plus sign (+) in this column indicates that this species comprised at least 5 percent of at least one collection. A double minus sign (=) indicates that this species comprised less than 0.5 percent of all collections. A question mark indicates that this species was very common at one and very scarce at a different location or a different time of the year and perhaps by a different author.

[b] Reference A: U.S. Department of Agriculture, Rural Electrification Administration. Merom Generating Station and Associated Transmission -- Final Environmental Impact Statement. USDA-REA-ES(ADM)-76-10-F. U.S. Department of Agriculture, Washington, D.C., 1977.

Reference B: Fisher, R.E. and H.P. Brown. White County Surface Water Resources. Illinois Department of Conservation, Division of Fisheries Publication, 1971.

Reference C: Whitney, L.S., Professor of Zoology, Personal Communication, Division of Life Sciences, Eastern Illinois University, Charleston, Illinois, 1978.

Reference D: Parmalee, P.W. The Fresh-Water Mussels of Illinois, Popular Science Survey, Vol. VIII, Printed by Authority of the State of Illinois, Springfield, Illinois, 1967.

Reference E: Townsend, L.E. Personnel communication. U.S. Environmental Protection Agency, Central District Office, 536 S. Clarck Street, Chicago, Illinois 60604. 1978.

Reference F: Page, L.M. and P.W. Smith. The Life History of the Dusky Darter, *Percina sciera* in the Embarras River, Illinois. Illinois Natural History Survey, Biological Notes No. 69, State of Illinois, Department of Registration and Education, Natural History Survey Division, Urbana, Illinois, September 1970.

Reference G: Krumholz, L.A., R.L. Bingham, and F.R. Meyer. A Survey of the Commercially Valuable Mussels of the Wabash and White Rivers of Indiana. Proceedings of the Indiana Academy of Science for 1969, 79:205-226, 1970.

TABLE A-IV-8. A COMPLETE SUMMARY OF THE KINDS AND AMOUNTS OF COMMERCIAL FISHES CAUGHT DURING THE PERIOD 1956-1975[a]

(Numbers Represent Pounds Per Year)

	Number of Years With Values > 0*	Arithmetic Mean	Geometric Mean	Unbiased Standard Deviation	Range (Year)
Fish taken by seine	10	3,510	1,910	4,300	350(1974) - 14,600(1957)
Fish taken by trap and hoop nets	20	73,000	68,000	30,000	40,805(1966) - 170,775(1973)
Fish taken by baskets	5	510	300	550	60(1964) - 1,400(1956)
Fish taken by troutline (hooks)	8	620	300	770	20(1974) - 2,350(1956)
Total fish taken	20	75,000	70,000	30,000	40,805(1966) - 173,030(1973)
Carp	20	28,000	24,000	18,000	9,992(1967) - 82,230(1973)
Buffalo	20	14,900	13,800	6,800	6,905(1966) - 34,176(1973)
Drum	20	3,700	3,200	2,000	1,303(1962) - 8,965(1956)
Catfish	20	14,900	14,100	5,200	7,810(1962) - 27,668(1973)
Bullheads	6	110	60	150	20(1969) - 400(1974)
Sturgeons	20	2,000	1,400	1,900	210(1967) - 8,620(1956)
Paddlefish	19	420	320	280	50(1962) - 1,149(1974)
White carp	20	9,600	7,500	5,900	1,850(1959) - 19,487(1973)
Suckers	20	600	290	780	20(1972) - 3,200(1956)
Gars	5	2,000	310	3,100	6(1962) - 7,300(1965)
Bowfin	6	140	90	110	20(1971) - 310(1970)
Mooneye and goldeye	2	75	71	35	50(1973) - 100(1975)
Eel	14	130	80	140	6(1962) - 535(1973)
Crappies	1	25	25	0	25(1962) - 25(1962)
Number of commercial fishermen	20	23	22	4	17(1959) - 30(1963)

*A value of zero may indicate that this parameter was not measured. These values are not included in the subsequent statistical treatment of the data.

[a] Johnson, T. Personal Communication. Southern Streams Project Biologist, State of Illinois, Department of Conservation, 1327 South Lincoln, Centralia, Illinois 62801, 1978.

TABLE A-IV-9. SPAWNING HABITS OF COMMONER FISH SPECIES THAT EXIST NEAR WHITE COUNTY*

Species	Spawning Habitat	Probability of Spawning in Intake Channel or Arm
Gizzard shad	Shallow water; broadcasts eggs near surface	Low
Goldeye	Shallow and firm bottom sites	Low
Carp	Shallow water; broadcasts eggs over vegetation, debris and rubble	Low
Channel catfish	Semi-dark, secluded nests in holes, undercut bank, log jams, rocks	Moderate
Black bullhead	Nests in shallow water in moderate to heavy vegetation	Low
Largemouth bass	Nests in shallow water or soft mud or marl in vegetated areas	Low
Bluegill	Nests in shallow water (<75 cm)	Low

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*U.S. Department of Agriculture, Rural Electrification Administration. Merom Generating Station and Associated Transmission -- Final Environmental Impact Statement. USDA-REA-ES(ADM)-76-10-F. U.S. Department of Agriculture, Washington, D.C., 1977.

TABLE A-IV-10. BONY AND CARTILAGINOUS FISHES PRESENT IN THE WABASH RIVER OR ITS TRIBUTARIES IN OR NEAR WHITE COUNTY, ILLINOIS

Common Name	Scientific Name	Very Common[a]	Of interest to sport fisherman	Of interest to commercial fisherman	Prefers slower waters	Found in the Wabash River	Found in its tributaries	Found in lakes and impoundments	Reference[b]
Golden shiner	Notemigonus crysoleucas (Mitchill)	=						+	B,A,G,J
Yellow bullhead	Ictalurus natalis (Lesueur)	+					+	+	B,K,A,C,F,G,J
Silverjaw minnow	Ericymba buccata (Cope)	-				+	+		A,G,H,I,J,K
Emerald shiner	Notropis atherinoides	+				+	+		A,D,E,J,K
Bluntnose minnow	Pimephales notatus (Rafinesque)	+				+	+		A,D,G,J,K
Northern bullhead minnow	Pimephales vigilax perspicuus	+				+	+		A,D,E,H,I,J,K
Creek chub	Semotilus atromaculatus latus	+				+	+		A,F,G,J,K
White sucker	Catostomus commersoni (Lacepede)	?				*	+	*	A,C,G,J,K
Blackstripe topminnow	Fundulus notatus (Rafinesque)	+				+	+		A,D,E,J,K
Spotted sucker	Minytrema melanops (Rafinesque)	+				+			A,F,G,J
Smallmouth bass	Micropterus dolomieui (Lacepede)	+	+		+	+			A,D,F,J,K
Longear sunfish	Lepomis megalotis (Rafinesque)	?	+		+	+			A,D,E,F,G,J,K
Johnny darter	Etheostoma nigrum (Rafinesque)	-			+	+			A,F,H,J,K
Pumpkinseed	Lepomis gibbosus (Linnaeus)					+			B,J
Black bullhead	Ictalurus melas (Rafinesque)				*	*	*		C,J
Redear sunfish	Lepomis microlophus (Gunther)	=				+	*		C,J,K
Yellow bass	Roccus mississippiensis (Jordan and Eigenmann)				*	+	*		C,G,J,K
Western silver minnow (silvery minnow)	Hybognathus nuchalis nuchalis (Agassiz)	+			+	+			D,J,K
Ghost shiner	Notropis buchanani	+				+			D,J,K
Spotfin shiner	Notropis spilopterus (Cope)	+			+	+			D,E,H,J,K
Common shiner	Notropis cornutus (Mitchill)	+					+		G,J,K
Greenside darter	Etheostoma blenniodes (Rafinesque)	-				-		+	G,J,H
Northern madtom	Noturus stigmosus (Taylor)	=				+	+		H
Northern dusky darter	Percina sciera sciera (Swain)	-				+	+		H,J,K
Steelcolor shiner	Notropis whipplei (Girard)	+					+	+	H,J,K,E,G
Stoneroller	Campostoma anomalum	-					+		H,K
Northern hogsucker	Hypentelium nigricans	-				+	+		H,I,J
Rainbow darter	Etheostoma caeruleum (Storer)	-			-		+		H,J
Orange-throat darter	Etheostoma spectabile spectabile (Agassiz)	-					+		H,J
Darter	Etheostoma chlorosomum	-					+		H
Slough darter	Ehteostoma gracile (Girard)	-					+		H,J
Fantail darter	Ehteostoma flabellare	-					+		H
Harlequin darter	Etheostoma histrio	-					+		H,J
Eastern sand darter	Ammocrypta pellucida (Baird)	-					+		H,J
Blackside darter	Percina maculata (Girard)	=				+	+		H,J,D
Chestnut lamprey	Ichthyomyzon castaneus (Girard)	=				+	+		H,K,M
Brook lamprey	Lampetra lamottei (Lesueur)						*		J
Lake sturgeon	Acipenser fulvescens (Rafinesque)					*			J
Paddlefish	Polyodon spathula (Walbaum)	-				+	+		J,K
Spotted gar	Lepisosteus oculatus (Winchell)	=				+	+	*	J,K
Northern bigeye chub	Hybopsis amblops amblops (Raf).	=				+	+		J
River chub	Hybopsis micropogon (Cope)					+			J,K
Gravel chub	Hybopsis x-punctata	=				+	+		J
Bigeye shiner	Notropis boops (Gilbert)								
Striped shiner	Notropis chrysocephalus chrysocephalus (Rafinesque)								J
Redfin shiner	Notropis umbratilis (Girard)	-					+		J,K
Pugnose minnow	Opsopoeodus emiliae (Hay)								J

(continued)

TABLE A-IV-10. (continued)

Common Name	Scientific Name	Very common[a]	Of interest to sport fisherman	Of interest to commercial fisherman	Prefers slower waters	Found in the Wabash River	Found in its tributaries	Found in lakes and impoundments	Reference[b]
Tadpole madtom	*Noturus gyrinus* (Mitchill)	+				+	+		D,G,J,K
Brindled madtom	*Noturus miurus* (Jordan)	+					+		D,G,J,K
Mud darter	*Etheostoma asprigene* (Forbes)	-				+	+		D,E,H,J,K
Slender head darter	*Percina phoxocephala* (Nelson)	-				+	+		D,E,H,J,K
Skipjack herring	*Alosa chrysochloris* (Rafinesque)	-				+	+		D,E,J,K F
Silver chub	*Hybopsis storeriana*	-				+			D,E,J,K
River shiner	*Notropsis blennius* (Girard)	+				+			D,E,J,K
Northeastern sand shiner	*Notropsis stramineus stramineus* (Cope)	-				+	+		D,E,I,J
Mimic shiner	*Notropsis volucellus* (Cope)	-				+			D,E,J
Suckermouth minnow	*Phenacobius mirabilis* (Girard)	-				+	+		D,K,E,H,I,J
Mountain madtom	*Noturus eleutherus* (Jordan)	?			-	+	+		D,E,J,K
Brook silverside	*Labidesthesis sicculus* (Cope)	?				+	+		D,G,J,K
Shortnose gar	*Lepisosteus platostomus* (Raf.)	?		+		+	+		D,F,J,K
Silver lamprey	*Ichthyomyzon unicuspis*	-				+	+		D,G,J,K
Highfin carpsucker	*Carpiodes velifer* (Rafinesque)	-				+	+		D,J,K
Golden redhorse	*Moxostoma erythrurum* (Rafinesque)	?				+	+		A,D,J,K
Bigmouth buffalo	*Ictiobus cyprinellus* (Valenciennes)	-				+			D,J,K
Speckled chub	*Hybopsis aestivalis* (Girard)				-	+	+		E,J
Mosquito fish	*Gambusia affinis affinis* (Baird & Girard)	-				+			E,J,K
Threadfin shad	*Dorosoma petense* (Gunther)	-				+			E,K
Flathead minnow		-				+			F
White catfish	*Ictalurus catus* (Linnaeus)	-				+			F
Rock bass	*Ambloplites rupestris* (Raf.)	-					+		G
Grass pickerel	*Esox americanus vermiculatus* (Lesueur)	-				+	+		G,J,K,E
Blue sucker	*Cycleptus elongatus* (Lesueur)	-		+		+	+		J,K
Western creek chubsucker	*Erimyzon oblongus claviformis* (Girard)	-					+		J,K
Lake chubsucker	*Erimyzon sucetta* (Lacepede)	-							
Black buffalo	*Ictiobus niger* (Rafinesque)					*	*		J,
Stonecat	*Noturus flavus* (Rafinesque)	-				+			J
Pirate perch	*Aphredoderus sayanus* (Gilliams)	-					+		J
White bass	*Roccus chrysops* (Rafinesque)	-				+			J,K
Flier	*Centrarchus macropterus*				+		*	*	J
Orangespotted sunfish	*Lepomis humilis* (Girard)	-				+	+		J,K
Bluebreast darter	*Etheostoma camurum* (Cope)	-				+	+		J,K
Iowa darter	*Etheostoma exile* (Girard)							*	J
Stripetail darter	*Etheostoma kennicotti* (Putman)						*		J
Spottail darter	*Etheostoma squamiceps* (Jordan)	-				+	*		J,K
River darter	*Percina shumardi* (Girard)				-	+			J
Channel darter	*Percina copelandi* (Jordan)						*		J
Stargazing darter	*Percina uranidea* (Jordan & Gilbert)					*			K
Alabama shad	*Alosa alabamae* (Jordan & Everman)	-				+			K
Goldfish	*Carassius auratus* (Linnaeus)	-				+			K
Silverband shiner	*Notropis shumardi* (Girard)	-				+			K
Black redhorse	*Moxostoma duquesnei* (Lesueur)	-				+			K
Hybrid sunfish		-				+	+		K
Shortnose gar	*Lepisosteus platostomus* (Raf.)	-				+			K,M
Hornyhead chub	*Nocomis biguttatus* (Kirtland)	-				+			K,M
Quillback carpsucker	*Carpoides cyprinus*	-		+		+	+		B,D,G,K
Black crappie	*Pomoxis nigromaculatus* (Lesueur)	-	+			+	+	+	B,C,D,E,J,K

(continued)

TABLE A-IV-10. (continued)

Common Name	Scientific Name	Very Common[a]	Of interest to sport fisherman	Of interest to commercial fisherman	Prefers slower waters	Found in the Wabash River	Found in its tributaries	Found in lakes and impoundments	Reference[b]
Gizzard shad	Dorosoma cepedianum (Lesueur)	++			+	+	+		A,K,D,E,F,G,J
Northern river carpsucker	Carpiodes carpio carpio (Raf.)	+		+		+	+		A,D,E,G,J,K
Northern redhorse	Moxostoma macrolepidotum (Lesueur)	?				+			A,D,G,J
Longnose gar	Lepisosteus osseus (Linnaeus)	?		+		+	+		A,K,B,C,D,E,J
Flathead catfish	Pylodictus olivaris (Rafinesque)	+	+	+		+	+		A,J,B,K,D,E,F,G
Channel catfish	Ictalurus punctatus (Rafinesque)	+	+	+		+	+		A,J,B,K,D,E,F,G
Sauger	Stizostedion canadense (Smith)	-	+			+	+		A,C,E,J,K
Centrarchids		-	+			+			A
White bass	Monrone chrysops	-	+		+	+	+		A,C,D,E,K
American eel	Anguilla rostrata (Lesueur)	?		+		+			A,B,D,J,K
Carp	Cyprinus carpio (Linnaeus)	+		+		+	+	*	A,K,B,C,D,F,G,J
Goldeye	Hiodon alosoides (Rafinesque)	?				+	+		A,J,K,F
Mooneye	Hiodon tergisus	?				+			A,J,K
Freshwater drum	Aplodinotus grunniens (Raf.)	+	+	+		+	+	*	A,B,C,D,E,J,K
Largemouth bass	Micropterus salmoides salmoides (Rafinesque)	-	+			+	+	+	B,C,D,G,J,K
Northern bluegill	Lepomis macrochirus macrochirus	?	+			+	+	+	B,C,D,G,J,K
Kentucky spotted bass							+		B,C,D
Warmouth	Chaenobryttus gulosus (Cuvier)	=					+	+	B,C,J,K
White crappie	Pomoxis annularis (Rafinesque)	-	+			+	+	+	B,K,A,C,D,G,J
Green sunfish	Lepomis cyanellus (Rafinesque)	+				+	+	+	B,K,A,C,D,F,G,J
Smallmouth buffalo	Ictiobus bubalus (Rafinesque)	-		+		+	+		B,D,J,K
Spotted bass	Micropterus punctularus (Raf.)	+	+			+	+		B,J,A,K,D,E,G,H,I
Shovelnose sturgeon	Scaphirhynchus platorynchus (Raf.)	=	+			+			B,D,J,k
Paddlefish	Polyodon spathula (Walbaum)	=	+			+			B,K,M
Whitecarp			+			+			B,K
Bowfin	Amia calva (Linnaeus)	=	?			+	+	*	B,J,K
Blue catfish	Ictalurus furcatus (Lesueur)	=	+	+		+	+		B,J,K
Silver redhorse	Moxostoma anisurum	=				+			K
Shorthead redhorse	Moxostoma aureolum	-					+		K
Orangethroat darter	Etheostoma spectabile (Agassiz)	=					+		K,M

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[*] The habitat of this species indicates that it is likely to be found in this location.

[a] A plus sign (+) in this column indicates that this species comprised at least 5 percent of at least one collection. A double minus sign (=) indicates that this species comprised less than 0.5 percent of all collections. A question mark (?) indicates that this species was very common at one and very scarce at a different location, time of the year, or when studied by a different author.

[b] Reference A: U.S. Department of Agriculture, Rural Electrification Administration. Merom Generating Station and Associated Transmission -- Final Environmental Impact Statement. USDA-REA-ES(ADM)-76-10-F. U.S. Department of Agriculture, Washington, D.C. 1977.

(continued)

TABLE A-IV-10. (continued)

Reference B: Fisher, R.E. and H.P. Brown. White County Surface Water Resources. Illinois Department of Conservation, Division of Fisheries Publication, 1971.

Reference C: Illinois, State of Illinois Outdoor Recreation. Department of Conservation, 605 State Office Building, 400 South Spring Street, Springfield, Illinois 62706, 1974.

Reference D: NHS Fish Collection. Little Wabash River and Wabash River in White County, Illinois, 1950-Present.

Reference E: Page, L.M. Personal Communication. Illinois Natural History Survey, Natural Resources Building, Urbana, Illinois 61801, 1977.

Reference F: Beck, R.W. and Associates. Environmental Analysis Merom Generating Station for Hoosier Energy Division of Indiana Statewide R.E.C., Inc., 1976.

Reference G: Townsend, L.E. Personal Communication. U.S. EPA Central District Office, 536 S. Clark Street, Chicago, Illinois 60604, 1978.

Reference H: Page, L.M. and P.W. Smith. The Life History of the Dusky Darter, Percina sciera in the Embarras River, Illinois. Illinois Natural History Survey Biological Notes No. 69. State of Illinois, Department of Registration and Education, Natural History Survey Division, Urbana, Illinois, 1970.

Reference I: Page, L.M. and P.W. Smith. The Life History of the Slenderhead Darter, Percina phoxocephala, in the Embarras River, Illinois, Illinois Natural History Survey Biological Notes No. 74, Urbana, Illinois, State of Illinois, Department of Registration and Education, Natural History Survey Division, 1971.

Reference J: Smith, P.W. A Preliminary Annotated List of the Lampreys and Fishes in Illinois. Illinois Natural History Survey, Biological Notes No. 54, Urbana, Illinois. State of Illinois, Department of Registration and Education, Natural History Survey Division, 1965.

Reference K: Johnson, T. Personal Communication. Southern Stream Project Biologist, State of Illinois, Department of Conservation, 1327 South Lincoln, Centralia, Illinois 62801, 1978.

Reference L: Smith, P.W. A Key to the Fishes of Illinois. Fishery Bulletin No. 6, Department of Conservation, Division of Fisheries, Springfield, Illinois 62706, 1973.

Reference M: State of Illinois. Rare and Endangered Fish of Illinois. Department of Conservation, Division of Fisheries, Springfield, Illinois, 62706, 1973.

TABLE A-IV-11. FISH DIVERSITY INDEX AT LOCATIONS ALONG THE WABASH RIVER IN OR NEAR WHITE COUNTY, ILLINOIS

Location	Capture Technique	Total Different Kinds of Species	Total Individuals (N)	Date Collected	Diversity Index (D)	Reference[a]
.0 km N of Darwin	electrofishing	17	109	July 17, 1975	2.691	D
	minnow seining	8	236	July 17, 1975	2.186	D
	sum of above	23	345	July 17, 1975	2.912	D
0.8 km N of Darwin	electrofishing	14	77	July 17, 1975	(2.344)*	D
	minnow seining	9	154	July 17, 1975	1.551	D
	netting	3	23	July 17, 1975	(0.912)*	D
	sum of above	22	254	July 17, 1975	2.836	D
8 km S of Darwin	electrofishing	16	142	July 17, 1975	2.050	D
	minnow seining	11	171	July 17, 1975	1.947	D
	sum of above	24	313	July 17, 1975	2.567	D
Darwin power plant	electrofishing	10	71	July 1975	(2.111)*	D
	minnow seining	10	175	July 1975	2.303	D
	sum of above	20	246	July 1975	3.114	D
Old York	electrofishing	12	70	July 18, 1975	(2.362)*	D
	minnow seining	8	202	July 18, 1975	2.477	D
	sum of above	19	272	July 18, 1975	3.206	D
Hutsonville power plant	electrofishing	12	103	July 1975	2.234	D
	minnow seining	12	56	July 1975	(2.699)*	D
	sum of above	21	159	July 1975	3.095	D
Hutsonville	electrofishing	14	124	July 17, 1975	1.961	D
	minnow seining	5	36	July 17, 1975	(1.954)*	D
	netting	3	3	July 17, 1975	(1.585)*	D
	sum of above	18	163	July 17, 1975	2.685	D
Merom, Indiana	electrofishing	24	229	July 14, 1977	3.123	D
		9	296	August 1975	2.017	B
		18	399	October 1975	2.147	B
	electrofishing	17	67	July 22, 1975	(3.445)*	D
	minnow seining	7	23	July 22, 1975	(2.403)*	D
	sum of latter 2	22	90	July 22, 1975	(3.916)*	D
8 km N of Russellville	electrofishing	13	33	July 1975	(3.427)*	D
	minnow seining	8	64	July 1975	(2.194)*	D
	sum of above	18	97	July 1975	(3.356)*	D
Russellville	electrofishing	4	9	July 21, 1975	(1.658)*	D
	minnow seining	8	494	July 21, 1975	1.431	D
	netting	6	18	July 21, 1975	(1.880)*	D
	sum of above	15	521	July 21, 1975	1.686	D
10 km S of Russellville	electrofishing	12	50	July 21, 1975	(2.984)*	D
	minnow seining	8	99	July 21, 1975	(1.730)*	D
	sum of above	17	149	July 21, 1975	2.913	D
Vincennes, Indiana	electrofishing	14	55	July 22, 1975	(3.075)*	D
	minnow seining	4	177	July 22, 1975	1.402	D
	netting	5	26	July 22, 1975	(1.582)*	D
	sum of above 3	19	258	July 22, 1975	2.826	D
	electrofishing	14	200	July 13, 1977	2.654	D
St. Francisville	electrofishing	12	39	July 23, 1975	(3.099)*	D
	minnow seining	6	73	July 23, 1975	(1.409)*	D
	sum of above	16	112	July 23, 1975	2.851	D
6 km S of Pullves Mill	electrofishing	10	50	July 1975	(2.972)*	D
	minnow seining	1	2	July 1975	(0.000)*	D
	sum of above	11	52	July 1975	(3.093)*	D

(continued)

TABLE A-IV-11. (continued)

Location	Capture Technique	Total Different Kinds of Species	Total Individuals (N)	Date Collected	Diversity Index (D)	Reference[a]
Mt. Carmel Dam	electrofishing	9	33	July 25, 1975	(2.878)*	D
	minnow seining	2	11	July 25, 1975	(0.845)*	D
	netting	4	31	July 25, 1975	(1.338)*	D
	sum of above 3	11	75	July 25, 1975	(2.952)*	D
	electrofishing	15	107	July 13, 1977	2.635	D
	minnow seining	7	19	July 13, 1977	(2.392)*	D
	sum of above 2	19	126	July 13, 1977	2.958	D
Princeton power plant	electrofishing	11	39	July 1975	(2.990)*	D
	minnow seining	11	112	July 1975	2.387	D
	sum of above 2	19	151	July 1975	3.265	D
Rochester riffle	electrofishing	7	38	July 23, 1975	(2.314)*	D
	minnow seining	7	21	July 23, 1975	(2.392)*	D
	sum of above 2	14	59	July 23, 1975	(3.209)*	D
11 km E of Cowling	electrofishing	13	104	July 1975	2.510	D
	minnow seining	10	73	July 1975	(2.302)*	D
	sum of above 2	19	177	July 1975	3.311	D
Grayville		20	186	July 9, 1964	2.638	A
		15	45	August 9, 1967	(3.178)*	A
		10	10	August 1970	(3.322)*	A
	electrofishing	12	132	July 28, 1975	1.493	D
	minnow seining	3	88	July 28, 1975	(1.104)*	D
	netting	7	21	July 28, 1975	2.498	D
	sum of above 3	15	241	July 28, 1975	2.417	D
	electrofishing	15	109	July 12, 1977	3.244	D
New Harmony, Indiana		12	27	August 9, 1977	(2.837)*	
	electrofishing	19	249	July 28, 1975	2.110	D
	minnow seining	9	83	July 28, 1975	(2.292)*	D
	netting	5	22	July 28, 1975	(1.746)*	D
	sum of above 3	26	354	July 28, 1975	2.849	D
	electrofishing	19	203	July 12, 1977	3.136	D
	minnow seining	8	211	July 12, 1977	1.906	D
	sum of above 2	22	414	July 12, 1977	3.053	D
1.1 km NE of Maunie		13	149	Sept. 6, 1961	1.914	A
		17	126	August 9, 1967	2.214	A
	electrofishing	12	90	July 28, 1975	(2.553)*	D
	minnow seining	4	35	July 28, 1975	(0.911)*	D
	netting	10	16	July 28, 1975	(3.156)*	D
	sum of above 3	17	141	July 28, 1975	3.119	D
	electrofishing	12	41	July 12, 1977	(2.870)*	D
13 km E of New Haven, Indiana	electrofishing	16	70	July 29, 1977	(3.184)*	D
	minnow seining	5	65	July 29, 1977	(1.267)*	D
	sum of above 2	19	135	July 29, 1977	3.159	D
9.6 km E of New Haven, Indiana		12	18	August 8, 1967	(2.417)*	A
Confluence of Little Wabash and Wabash River	netting	8	34	July 1975	(2.264)*	D
6 km S of New Haven	electrofishing	9	48	July 29, 1975	(1.894)*	D
	minnow seining	7	50	July 29, 1975	(2.526)*	D
	sum of above 2	15	98	July 29, 1975	(3.171)*	D
	electrofishing	17	103	July 11, 1977	3.337	D
	minnow seining	8	163	July 11, 1977	2.365	D
	sum of above 2	19	266	July 11, 1977	3.250	D
14 km NE of Shawneetown	electrofishing	13	70	August 1, 1975	(2.675)*	D
	minnow seining	8	100	August 1, 1975	2.099	D
	netting	4	20	August 1, 1975	(1.437)*	D
	sum of above	16	190	August 1, 1975	3.218	D
4.8 km S of Rising Sun		20	228	August 20, 1964	2.834	A

(continued)

TABLE A-IV-11. (continued)

*The sample size makes the significance of this particular diversity index questionable.

[a] Reference A: NHS Fish Collection. Little Wabash River and Wabash River in White County, 1950-present.

Reference B: Beck, R.W. and Associates. Environmental Analysis Merom Generating Station for Hoosier Energy Division of Indiana Statewide R.E.C., Inc., 1976.

Reference C: Townsend, L.E. Personal Communication. U.S. Environmental Protection Agency, Central District Office, 536 S. Clark Street, Chicago, Illinois 60604. 1978.

Reference D: Johnson, T. Personal Communication. Southern Stream Project Biologist, 1327 South Lincoln, Centralia, Illinois 62801. State of Illinois, Department of Conservation, 1978.

TABLE A-IV-12. FISH DIVERSITY INDEX IN THE LITTLE WABASH RIVER

Location	Capture Technique	Total Different Kinds of Species	Total Individuals (N)	Date Collected	Diversity Index (D)	Reference[a]
3.2 Km. S. of Carmi		7	231	November 14, 1973	1.576	A
4.0 Km. E. of Brownsville		16	80	August 3, 1962	(3.123)*	A
1.6 Km. S.W. of Emma		14	17	August 16, 1968	(3.735)*	A
4.0 Km. S.W. of Golden Gate	electrofishing	13	118	July 27, 1976	2.855	B
	minnow seine	2	2	July 27, 1976	(1.000)*	B
	sum of above	14	120	July 27, 1976	2.919	B
8.0 Km. S. of Golden Gate	electrofishing	26	209	July 28, 1976	3.204	B
	minnow seine	11	87	July 28, 1976	(2.596)*	B
	sum of above	29	296	July 28, 1976	3.676	B
3.2 Km. E.and 1.6 Km S.of Wynoose	electrofishing	14	48	July 28, 1976	(3.182)*	B
	minnow seine	7	57	July 28, 1976	(1.943)*	B
	sum of above	18	105	July 28, 1976	3.274	B
3.2 Km. S.W. of Black	minnow seine	8	78	July 29, 1976	(1.860)*	B
4.0 Km W. of Effingham	minnow seine	16	319	August 3, 1976	2.860	B
4.8 Km. W. of St. Marys	minnow seine	19	318	August 3, 1976	3.512	B
1.6 Km N. of Louisville	electrofishing	19	131	August 6, 1976	3.733	B
	minnow seine	6	111	August 6, 1976	1.823	B
	sum of above	19	242	August 6, 1976	3.376	B
New Haven	electrofishing	19	115	August 9, 1976	3.503	B
	minnow seine	3	35	August 9, 1976	(0.605)*	B
	sum of above	20	150	August 9, 1976	3.399	B
Emma Bridge	electrofishing	12	79	August 9, 1976	3.078	B
4.8 Km. N.W. Herald	electrofishing	12	41	August 9, 1976	(3.044)*	B
4.0 Km. S.W. of Watson	electrofishing	18	167	August 10, 1976	3.308	B
	minnow seine	16	165	August 10, 1976	2.726	B
	sum of above	28	332	August 10, 1976	3.722	B
[illegible]	electrofishing	13	79	August 10, 1976	(2.290)*	B
4.0 Km. S.W. of Nord	electrofishing	11	42	August 11, 1976	(2.611)*	B
2.4 Km. N. of Clay City	electrofishing	14	58	August 11, 1976	(3.224)*	B
6.4 Km. S.E. of Clay City	electrofishing	13	69	August 11, 1976	(2.823)*	B
	minnow seine	2	5	August 11, 1976	(0.722)*	B
	sum of above	14	74	August 11, 1976	(2.945)*	B
2.4 Km. S. of Carmi	electrofishing	17	55	August 12, 1976	(3.560)*	B
Carmi	electrofishing	18	94	August 12, 1976	(3.191)*	B
6.4 Km S.E. of Louisville	minnow seine	4	65	August 13, 1976	(1.177)*	B
9.7 Km. E. of Grayville	minnow seine	13	205	August 16, 1976	2.411	B
6.4 Km. W. of Crossville	electrofishing	11	70	August 16, 1976	(2.446)*	B
Carmi	minnow seine	7	28	August 19, 1976	(2.272)*	B
Sum of all locations above except first three	electrofishing	46	1335	July-August 1976	4.017	B
	minnow seine	37	1475	July-August 1976	3.983	B
	sum of these two methods	59	2810	July-August 1976	4.394	B

*The statistical significance of samples of less than 100 individuals is open to question.

[a] Reference A: NHS Fish Collection. Little Wabash River and Wabash River in White County. 1950-Present.

Reference B: Johnson, T. Personal Communication. Southern Stream Project Biologist, State of Illinois, Department of Conservation, 1327 South Lincoln, Centralia, Illinois, 62801, 1978.

TABLE A-IV-13. FISH DIVERSITY INDEX IN TRIBUTARIES TO THE WABASH RIVER

Location	Total Different Kinds of Species	Total Individuals (N)	Date Collected	D	Reference[b]
Turtle Creek near Merom	9	63	August 1975	(2.287)*	B
At three locations on Clear Creek North of Monroe Reservoir approximately 17 km S of Bloomington, IN	5[a]	118	January 30, 1976	0.873a	C
	6	43	March 12, 1976	(2.162)*	C
	12	30	February 25, 1976	(3.133)*	C
Salt Creek from a point approximately 0.5 creek km SE of the Monroe Reservoir Dam extending approximately 38 creek km to a point approximately 4.2 km WSW Bedford	19	269	March 1976	3.128	C
White River from a point ca. 0.2 km SSW of Williams extending ca. 30 river km to a point ca. 5.7 km SSE of Bedford	18	96	March 1976	3.376	C
Clear Creek between New and Old bridge on Highway 37 at Harrodsburg	9	33	September 9, 1976	(2.827)*	C

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[a] "Minnows" included as a species without attempting individual species identification

* Based on insufficient data.

[b] Letters refer to footnotes to Table A-IV-9.

TABLE A-IV-14. CHANGE IN SPECIES OF FISHES FOUND IN THE WABASH RIVER 1967-1975*

Species Present in 1967 Survey; Absent in 1975 survey
Wabash River

Species	Number of Stations	Number of Fish
Mimic shiner	3	3
Bigmouth buffalo	2	2
Black buffalo	2	2
Northern redhorse	2	2
Yellow bullhead	1	1
Smallmouth bass	5	8
Longear X Green	2	2
Sauger	4	4

Species Present in 1975 Survey; Absent in 1967 Survey
Wabash River

Species	Number of Stations	Number of Fish
Chestnut lamprey	3	3
Shovelnose sturgeon	1	1
Paddlefish	2	2
Spotted gar	2	2
Threadfin shad	2	25
Mooneye	2	2
Silverjaw minnow	1	1
Bigeye chub	2	13
Gravel chub	1	2
Hornyhead chub	1	3
Steelcolor shiner	3	20
Creek chub	3	12
Silver redhorse	1	1
Black redhorse	1	1
Golden redhorse	6	7
Mountain madtom	2	2
Tadpole madtom	1	1
Blackstripe topminnow	2	7
Mosquito fish	1	2
Brook silverside	3	3
Mud darter	1	1
Bluebreast darter	2	2
Johnny darter	4	5
Spottail darter	3	4
Dusky darter	1	1

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*Johnson, T. Personal Communication. Southern Stream Project Biologist, State of Illinois, Department of Conservation, 1327 South Lincoln, Centralia, Illinois 62801, 1978.

TABLE A-IV-15. AMPHIBIANS WHICH MAY BE PRESENT IN WHITE COUNTY, ILLINOIS[a]

Common Name	Scientific Name	Herbivorous	Carnivorous	Found in the Wabash River	Found in its Tributaries	Found in lakes and impoundments	Hundreds of eggs laid/female (Number in parenthesis is the eggs/clutch)	Reference[a]
Mudpuppy (waterdog)	Necturus maculosus (Rafinesque)	+	+	+	+	*	0.6-1.4	A,B
Dwarf siren (Western lesser siren)	Siren intermedia	-	+	*	+	*	>5	A,B
Spotted salamander	Ambrystoma maculatum (Shaw)	-	+	+	+		1	A,B
Marbled salamander	Ambrystoma opacum (Gravenhorst)		+		+	*	0.5-2(1)	A
Small-mouthed salamander	Ambrystoma texanum (Matthes)	-	+		+	*	7(4-30)	A,B
Eastern tiger salamander	Ambrystoma tigrinum tigrinum (Green)	-	+		+	*	10(50)	A,B
Newt	Diemictylus viridescens	-	+			*	2-3.5	A
Dusky salamander	Desmognathus fuscus				*		0.12-0.26	A
Red-backed salamander	Plethodon cinereus (Green)						(8-10)	A,B
Zigzag salamander	Plethodon dorsalis Cope				+			A,B
Slimy salamander	Plethodon glutinosus						(10-20)	A
Midwest two-lined salamander	Eurycea bislineata rivicola (Mittleman)	-	+		+	*	0.3(12-30)	A,B
Long-tailed salamander	Eurycea longicauda longicauda (Green)	+	+		+	+		A,B
Cave salamander	Eurycea lucifuga							A
American toad	Bufo terrestris	-	+				40-200	A
Woodhouse's toad	Bufo woodhousei			*	*	*	200	A
Cricket frog	Acris crepitans Harper	-	+	*	*	*	2.5	A,B
Spring peeper	Hyla crucifer				*	*	8-10(1)	A,B
Common tree frog	Hyla versicolor				*	*	18(30-40)	A,B
Swamp tree frog	Pseudacris nigrita				*	*	(1+)	A
Northern crawfish frog	Rana areolata circulosa (Rice & Davis)				+		70	A,B
Bullfrog	Rana catesbeiana Shaw	-	+	*	+	*	100-200	A,B,C
Wood frog	Rana sylvatica sylvatica LeConte		+		+		20-30	A,B
Leopard frog	Rana pipiens sphenocephata Schreber			*	*	*	30-65	A,B
Hellbender	Cryptobranchus alleganiensis alleganiensis (Daudin)	-	+	+	+		3-4(300-400)	A,B
Central newt	Notophthalmus viridescens louisianensis (Wolterstorff)							B
Dark-sided salamander	Eurycea longicauda melanopleura (Cope)	-	+	*	*	+		B
Slimy salamander	Plethodon glutinosus (Green)				+		0.2-0.3	B
Fowler's toad	Bufo woodhousei fowleri Hinckley				+	*		B
Upland chorus frog	Pseudacris triseriata feriarum (Baird)	-	+	+	+	*	1	B
Western chorus frog	Pseudacris triseriata triseriata (Wied)	-	+		+	*		B

*The habitat of this species indicates that it is likely to be found in these locations.

[a] Reference A: Parmalee, P.W. Amphibians of Illinois, Story of Illinois Series No. 10 Printed by Authority of the State of Illinois, Illinois State Museum, Springfield, IL 1954.

Reference B: Smith, D.W. The Amphibians and Reptiles and Illinois. Illinois Natural History Bulletin 28 (1). State of Illinois, Department of Registration and Education, Natural History Survey Division, Urbana, IL 1961.

Reference C: U.S. Department of Agriculture, Rural Electrification Administration. Meron Generating Station and Associated Trasmission - Final Environmental Impact Statement. USDA-RES-ES(ADM)-76-10-F. 1977.

TABLE A-IV-16. REPTILES WHICH MAY BE PRESENT IN WHITE COUNTY, ILLINOIS

Common Name	Scientific Name	Aquatic	Carnivorous	Herbivorous	Found in or near Wabash River	Found in or near its tributaries	Found in or near lakes and impoundments	Eggs/clutch	Reference[a]
Common snapping turtle	Chelydra serpentina serpentina (Linnaeus)	+	+	+	*	+	*	20-30	A,B,C
Alligator snapping turtle	Macrochelys temminicki (Troost)	+	+		+	+	*	15-50	A,B
Common musk turtle (Stinkpot)	Sternotherus odoratus (Latreille)	+	+	–	*	*	*	3-5	A,B
Common mud turtle	Kinosternon subrubrum	±	+					2-5	A
Eastern box turtle	Terrapene carolina carolina (Linnaeus)	–	+	+		+	*	3-8	A,B
Common map turtle	Graptemys geographica (LeSueur)	+	+	–	*	+	*	10-16	A,B,C
False map turtle	Graptemys pseudogeographica (Gray)	+	+	+	*	*	*	7-13	A,B
Midland painted turtle	Chrysemys picta marginata (Agassiz)	±	+	+		+	*	4-10	A,B
Southern terrapin	Pseudemys floridana hieroglyphica	+	+	–			*	10-12	A
Pond terrapin (Cooter)	Pseudemys scripta elegans (Weid)	+	+	+	*	+	*	5-22	A,B
Soft-shelled turtle	Trionyx ferox	+	+	–	*		*	5-31	A
Spineless (smooth) soft-shelled turtle	Trionyx multicus muticus (LeSueur)	+	+	–	*	+		18-20	A,B
Northern fence lizard, Swift	Sceloporus undulatus hyacinthinus (Green)	–	+	–	–			4-17	A,B
Western slender grass snake (legless lizard)	Ophisaurus attenuatus attenuatus (Cope)	–	+	–		+		12	A,B
Little brown skink	Lygosoma laterale	–	+	–				1-5	A
Five-lined skink	Eumeces fasciatus (Linnaeus)	–	+	–		+		6-15	A,B
Greater five-lined skink	Eumeces laticeps (Schneider)	–	+	–	+			6-10	A,B
Green water snake	Natrix cyclopion	+	+	–		*		12	A
Red bellied water snake	Natrix erythrogaster neglecta (Conant)	+	+	–	+	*		15	A,B
Diamond-backed water snake	Natrix rhombifera rhombifera (Hallowell)	+	+	–	+	*	*	25-32	A,B
Common water snake	Natrix sipedon (Linnaeus)	+	+	–	*	+	*	8-75	A,B,C
DeKay's snake (Midland brown snake)	Storeria dekayi wrightorum (Trapido)	–	+	–				5-23	A,B
Northern red-bellied snake	Storeria occipitomaculata occipitomaculata (Storer)	–	+	–				7-14	A,B
Ribbon snake	Thamnophis sauritus (Linnaeus)	+	+	–	*		*	5-20	A,B
Eastern garter snake	Thamnophis sirtalis sirtalis (Linnaeus)	±	+	–				25-30	A,B
Valery's ground snake	Haldea valeriae	–	+	–				< 10	A
Eastern hog-nosed snake	Heterodon platyrhinos (Latreille)	±	+	–	*			13-24	A,B
Northern ringed-necked snake	Diadophis punctatus edwardsi (Merrem)	±	+	–	*			2-6	A,B
Midwest worm snake	Carphophis amoenus helenae (Kennicott)	–	+	–			*	2-5	A,B
Western mud snake	Farancia abacura reinwardti (Schlegel)	+	+	–			*	20-100	A,B
Racer	Coluber constrictor	–	+	–				8-25	A
Rough green snake	Opheodrys aestivus	–	+	–			*	3-9	A
Pilot black snake	Elaphe obsoleta	–	+	–				7-22	A
Yellow-bellied king snake	Lampropeltis calligaster calligaster (Harlan)	–	+	–				9-14	A,B
Black king snake	Lampropeltis getulus niger (Yarrow)	±	+	–				3-14	A,B
Red milk snake	Lampropeltis doliata syspila (Cope)	–	+	–				6-16	A,B
Scarlet snake	Cemophora coccinea	–	+	–				8	A
Northern copperhead	Ancistrodon contortrix mokeson (Daudin)	–	+	–				2-11	A,B
Eastern spiny softshell	Trionyx spinifer spinifer (LeSueur)	+	+	–		+	*	9-25	B,C
Ground skink	Scincella laterale (Say)	–				+		5	B
Western earth snake	Virginia valeriae elegans (Kennicott)	–	+					5	B
Timber rattlesnake	Crotalus horridus horridus (Linnaeus)	–	+					8-9	B

*The habitat of this species indicates that it is likely to be found in these locations.

[a] Reference A: Parmalee, P.W. Reptiles of Illinois, Popular Science Series, Volume V, Printed by Authority of the State of Illinois, Springfield, IL. 1955.

Reference B: Smith, P.W. The Amphibians and Reptiles of Illinois. Illinois Natural History Survey Bulletin 28(1). State of Illinois, Department of Registration and Education, Natural History Survey Division, Urbana, IL. 1961 (Reprinted 1971).

Reference C: U.S. Department of Agriculture, Rural Electrification Administration. Merom Generating Station and Associated Transmission - Final Environmental Impact Statement. USDA-REA-ES (ADM)-76-10-F. U.S. Department of Agriculture, Washington, D.C. 1977.

TABLE A-IV-17. BIRDS LIKELY TO BE FOUND IN WHITE COUNTY AND THEIR HABITATS†

	Cornfields	Soybeans	Woodlands	Oat fields	Wheat fields	Pasture lands	Ungrazed grasslands	Fallow fields	Hayfields	Redclover fields	Alfalfa fields	Marshlands	Shrub-grown areas	Orchards	Forests	Plowed fields	Residential areas	% of Total Bird Count for White County, Il. May 8, '76	Arithmetic Avg. Eggs/Nest	Range: Eggs/Nest	% of Eggs Giving Fledgings	Broods/year
Great blue heron, Ardea herodias	S											S			S			0.1				
Green heron, Butorides virescens						S			S			S			S			0.1				
Little blue heron, Florida caerulea																						
Common egret, Casmerodius albus							S								S							
Jack-crowned night heron, Nycticorax	S			S		S						S										
East bittern, Ixobrychus exilis																						
Canada goose, Branta canadensis	W	W			W										W							
Blue goose, Chen caerulescens																						
Mallard, Anas platyrhynchos												S*			W							
Black duck, Anas rubrias												S*										
Blue-winged teal, Anas discors																						
Wood duck, Aix sponsa																		0.6				
Lesser scaup, Aythya affinis																						
Turkey vulture, Cathartes aura	S.W	S		W	W	S.W			S.W						S.W							
Black vulture, Coragyps atratus						W																
Red-tailed hawk, Buteo jamaicensis	W	W		W		S.W		W					S		S.W	S						
Red-shouldered hawk, Buteo platypterus	S					W			S						S.W	S						
Golden eagle, Aquila chrysaetos																						
Bald eagle, Haliaeetus leucocephalus																						
Marsh hawk, Circus cyaneus	W				W	S.W							W									
Sparrow hawk, Falco sparverius	S.W			S.W	S.W	S.W		S.W	S.W				S.W		S.W							
Bobwhite, Colinus virginianus	S.W	S		S.W	S	S*.W	S*	S*.W	S*.W	S*	S*		S.W	S	S.W	S		0.4				
Common gallinule, Gallinula chloropus																						
American coot, Fulica americana												S*										
Killdeer, Charadrius vociferus	S*	S		S	W	S*	S	S	S.W	S		S*				S						
American woodcock, Philohela minor						S																
Upland plover, Bartramia longicauda	S	S		S	S	S*		S	S*	S	S					S						
Spotted sandpiper, Actitis macularia	S	S										S*										
Herring gull, Larus argentatus																						
Ring-billed gull, Larus delawarensis																						
Rock dove, Columba livia																	S	1.0				
Mourning dove, Zenaidura macroura	S.W	S.W		S.W	S.W	S	S	S*.W	S.W	S	S	S	S.W	S	S.W	S	S	2.0				
Yellow-billed cuckoo, Coccyzus americanus					S	S		S	S			S	S	S	S							
Black-billed cuckoo, Coccyzus erythropthalmus						S									S	S						
Great horned owl, Bubo virginianus															S.W							
Barred owl, Strix varia															S							
Long-eared owl, Asio otus													W		W							

(continued)

TABLE A-IV-17. (continued)

	Cornfields	Soybeans	Woodlands	Oat fields	Wheat fields	Pasture lands	Ungrazed grasslands	Fallow fields	Hayfields	Redclover fields	Alfalfa fields	Marshlands	Shrub-grown areas	Orchards	Forests	Plowed fields	Residential areas	% of Total Bird Count for White County, IL. May 8, '76	Arithmetic Avg. Eggs/Nest	Range: Eggs/Nest	% of Eggs Giving Fledging	Broods/year
Short-eared owl, Asio flammeus	W			W				W														
Whip-poor-will, Caprimulgus vociferus													S		S							
Common nighthawk, Chlordeiles minor						S		S	S					S				0.9				
Chimney swift, Chaetura pelagica	S	S		S	S	S		S	S	S	S		S	S	S		S	0.6				
Ruby-throated hummingbird, Archilochus colubris									S									1.0				
Belted kingfisher, Megaceryle alcoyon			W			S						S	S		S,W							
Yellow-shafted flicker, Colaptes auratus	W		W	S,W		S,W	S	S,W	S,W	S	S		S,W	S	S,W	S,W	S*	0.7	7.4	5-12		
Pileated woodpecker, Dryocopus pileatus															S*,W							
Red-bellied woodpecker, Centurus carolinus	W	W	W	W		S,W		W					S,W		S*,W		W	0.7	4.5	3-5		1
Red-head woodpecker, Melanerpes erythrocephalus	S,W			S	S	S	S	S	S	S			S*,W		S*,W		S*,W	2.9	4.7	3-6		
Yellow-bellied sapsucker, Sphyrapicus varius															W					4-6		
Hairy woodpecker, Dendrocopos villosus			W			S,W		W					W			S	W		4.1	3-6		
Downy woodpecker, Dendrocopos pubescens	S,W		W	W		S,W		S	S				S,W		S*,W		S,W	0.1	5.0	3-6		
Eastern kingbird, Tyrannus tyrannus	S			S		S*		S,W	S,W	S	S	S*	S*	S*	S*,W	S		0.6	3.9	3-6	low	
Great crested flycatcher, Myiarchus crinitus	S					S		S	S				S	S	S*		S	0.9	5.1	3-7		
Eastern phoebe, Sayornis phoebe	S			S		S			S				S	S	S*		S*	0.1	4.8	3-6	17-41	2
Acadian flycatcher, Empidonax virescens														S	S*			0.4	3.2	2-5		
Traill's flycatcher, Empidonax traillii	S								S			S	S*						3.7	3-4	27	1
Eastern wood pewee, Contopus virens						S							S		S		S	0.3	3.1	2-5		
Horned lark, Eremophila alpestris	S*,W	S*,W		S*,W	S,W	S*,W	S	S*,W	S,W	S	S		S			S,W		0.3				
Bank swallow, Riparia riparia						S	S						S					1.9				
Rough-winged swallow, Stelgidopteryx ruficollis					S	S		S		S		S								4-8		
Barn swallow, Hirundo rustica	S	S		S	S	S	S	S	S	S	S		S	S			S*		4.6	3-7	21-70	
Cliff swallow, Petrochelidon pyrrhonota				S	S	S		S	S				S									
Purple martin, Progne subis	S	S		S	S	S		S	S								S	0.1	4.8	3-6		1
Blue jay, Cyanocitta cristata	S,W		W	S		S,W	S	S,W	S,W	S			S,W	S	S,W		S	1.4				
Common crow, Corvus brachyrhynchos	S,W	W	W	S,W	S,W	S,W	S	S,W	S,W	S	S	S	S,W	S	S,W	S		0.7				
Chickadee, Parus spp.	W		W			S,W		W	W				S,W		S,W	W						
Black-capped chicadee, Parus atricapillus																						
Carolina chickadee, Parus carolinensis						S								S				0.6				
Tufted titmouse, Parus bicolor	W		W		W								S,W	S	S,W		S	0.7				
White-breasted nuthatch, Sitta carolinensis	W		W			S,W							W		S,W			0.1				
Brown creeper, Certhia familiaris			W												W							
House wren, Troglodytes aedon						S							S	S	S		S	0.4				
Winter wren, Troglodytes troglodytes															W							
Bewick's wren, Thryomanes bewickii	S					S		S*					S	S	S							
Carolina wren, Thryothorus indovicianus	S,W		W			S		S,W					S,W	S	S		S	1.9				

(continued)

TABLE A-IV-17. (continued)

	Cornfields	Soybeans	Woodlands	Oat fields	Wheat fields	Pasture lands	Ungrazed grasslands	Fallow fields	Hayfields	Redclover fields	Alfalfa fields	Marshlands	Shrub-grown areas	Orchards	Forests	Plowed fields	Residential areas	% of Total Bird Count for White County, IL. May 8, '76.	Arithmetic Avg. Eggs/Nest	Range: Eggs/Nest	% of Eggs Giving Fledgings	Broods/year
Long-billed marsh wren, Telmatodytes palustris								W				S*										
Short-billed marsh wren, Cistothorus platensis							S		S*			S										
Mockingbird, Mimus polyglottos	S,W	S			S,W	S		S,W	S				S,W	S	W	S	S	0.3	3.8	3-6	1-18	
Catbird, Dumetella carolinensis	S				S	S			S			S	S	S	S		S	0.6	3.6	2-5	36-69	
Brown thrasher, Toxostoma rufum	S			S	S	S		S	S	S	S	S		S	S*	S	S	0.9	3.8	2-5	20-53	
Robin, Turdus migratorius	S,W	S		S	S,W	S,W	S	S,W	S	S	S	S	S,W	S	S,W	S	S	0.3		9		1
Wood thrush, Hylocichla mustelina						S*						S*	S		S*		S*	0.9	3.9	3-5	78	3-4
Hermit thrush, Hylocichla guttata													W		W							
Summer tanager, Piranga rubra						S				S					S							
Cardinal, Richmondena cardinalis	S,W			S	S,W	S,W		S,W	S		S		S,W	S	S,W		S	2.5				
Blue grosbeak, Guiraca caerulea													S		S							
Indigo bounting, Passerina cyanea	S	S		S	S	S	S	S	S	S	S		S	S	S	S		6.4				
Dickcissel, Spiza americana	S	S		S*	S*	S*	S*	S*	S*	S*	S*		S	S		S		0.7				
American goldfinch, Spinus tristis	S,W	S,W		S	W	S,W	S	S,W	S,W	S	S	S	S,W	S	S,W			1.9				
Rufourous-sided towhee, Pipile erythrophthalmus	S					S		S					S,W	S	S,W	S		0.6				
Savannah sparrow, Passerculus sandwichensis	W	S,W		S,W		S*	S*	S	S*	S*	S*	S	S									
Grasshopper sparrow, Ammodramus savannarum		S		S*	S*	S*	S*	S*	S*	S*	S*		S	S								
LeConte's sparrow, Passerherbulus candacutus				W				W														
Vesper sparrow, Pooecetes gramincus	S*	S*		S*		S*			S*	S	S		S	S								
Lark sparrow, Chondestes grammacus	S	S		S*	S	S*		S*	S				S		S	S						
Bachman's sparrow, Aimophila aestivalis				S		S*		S*	S				S									
Slate-colored junco, Unco hyemalis	W	W	W	W	W	W		W	W				W		W	W						
Tree sparrow, Spizella arborea	W		W	W	W	S,W		W	W			S	W		W	W						
Chipping sparrow, Spizella passerina	S			S		S		S						S			S					
Field sparrow, Spizella pusilla	S	S		S	S	S*	S	S*,W	S	S	S		S,W	S	S,W	S		2.5				
White-crowned sparrow, Zonotrichia leucophrys								W					W									
White-throated sparrow, Zonotrichia albicollis	W			W				W					W		W			0.1				
Fox sparrow, Passerella iliaca	W			W		W		W					W		W							
Swamp sparrow, Melospiza georgiana							S	W	S	S	S	S*	S,W		S,W							
Song sparrow, Melospiza melodia	S,W			S,W	S,W	S*,W	S	W	S,W			S	S,W	S	W		S	4.5				
Lapland longspur, Calcarius lapponicus	W	W			W	W			W							W						
Starling, Sturnus vulgaris	S,W	S		S,W	S,W	S,W	S	S,W	S,W	S	S	S	S,W	S	S,W	W	S	1.9				
American kestrel																		0.1				
Least flycatcher, Empidonax minimus													S*	S			S*	0.1	3.6	3-4		
Tree swallow, Iridoprocne bicolor	S											S*						0.6	5.4	4-7		
Swainson's thrush, Hylocichla guttata																		0.3	migrant only			
Veery, Catharus fuscescens																		0.3	migrant only			

(continued)

TABLE A-IV-17. (continued)

	Cornfields	Soybeans	Woodlands	Oat fields	Wheat fields	Pasture lands	Ungrazed grasslands	Fallow fields	Hayfields	Redclover fields	Alfalfa fields	Marshlands	Shrub-grown areas	Orchards	Forests	Plowed fields	Residential areas	% of Total Bird Count for White County, Il. May 8, '76	Arithmetic Avg. Eggs/Nest	Range: Eggs/Nest	% of Eggs Giving Fledglings	Broods/year
Eastern bluebird, Sialia sialis	S,W		W	S,W	W	S,W		S,W	S,W	S		S	S,W		S,W	S		0.3	4.7	3-6	38-95	2
Blue-gray gnatcatcher, Polioptila caerulea													S		S			0.9				
Ruby-crowned kinglet, Regulus calendula													S,W									
Water pipit, Anthus spinoletta																						
Sprague's pipit, Anthus spragueii																						
Cedar waxwing, Bombycilla cedrorum						W		W					W									
Loggerhead shrike, Lanius ludovicianus	S,W	S		S,W		S	S,W	S	S				W	S		S		0.3				
White-eyed vireo, Vireo griseus													S		S			0.3				
Bell's vireo, Vireo bellii						S							S									
Yellow-throated vireo, Vireo flavifrons															S			0.3				
Red-eyed vireo, Vireo olivaceus						S							S		S		S	0.3				
Warbling vireo, Vireo gilvus													S		S		S	1.4				
Black-and-white warbler, Mniotilta varia															S			0.3				
Prothonotary warbler, Protonotaria citrea													S		S			0.9				
Worm-eating warbler, Helmitheros vermivorus															S							
Swainson's warbler, Limnothlypis swainsonii																						
Parula warbler, Parula americana													S		S			0.2				
Yellow warbler, Dendroica petechia													S	S	S			0.9				
Myrtle warbler, Dendroica coronata													W									
Cerulean warbler, Dendroica cerulea															S							
Prairie warbler, Dendroica discolor													S									
Louisiana waterthrush, Seiurus motacilla															S							
Kentucky warbler, Oporornis formosus													S		S							
Yellowthroat, Geothlypis trichas	S			S	S	S		S*	S	S	S	S*	S	S	S			2.3				
Yellow-breasted chat, Icteria virens						S		S					S	S	S			0.6				
Hooded warbler, Wilsonia citrina															S			0.7				
American redstart, Setophaga ruticilla													S		S							
House sparrow, Passer domesticus	S,W	S,W		S,W	S,W	S,W	S	S,W	S,W	S	S		S,W	S	S,W	S,W	S	15.6				
Meadowlark, Sturnella spp.	S,W	S,W		S*,W	S*,W	S*,W	S*	S*,W	S*	S*	S*	S	S,W		S,W							
Eastern meadowlark, Sturnella magna														S		S		1.2				
Redwinged blackbird, Agelaius phoeniceus	S,W	S,W		S*	S*	S*,W	S*	S*	S*	S*	S*	S*	S,W	S	S,W	S		5.4				
Orchard oriole, Icterus spurius	S				S	S		S	S	S			S	S	S			0.3				
Baltimore oriole, Icterus galbula	S			S	S	S				S			S	S	S							
Rusty blackbird, Euphagus carolinus	W																					
Common grackle, Quiscalus quiscula	S	S		S	S	S	S	S	S	S	S	S*	S	S	S	S	S	9.7				
Brown-headed cowbird, Molothrus ater	S	S*		S*,W	S*,W	S*	S	S*	S*	S*	S*	S*	S*	S,W	S	S	S	2.6				
Scarlet tanager, Piranga olivacea														S		S		0.1				

(continued)

TABLE A-IV-17. (continued)

	Cornfields	Soybeans	Woodlands	Oat fields	Wheat fields	Pasture lands	Ungrazed grasslands	Fallow fields	Hayfields	Redclover fields	Alfalfa fields	Marshlands	Shrub-grown areas	Orchards	Forests	Plowed fields	Residential areas	% of Total Bird Count for White County, Il. May 8,'76	Arithmetic Avg. Eggs/Nest	Range: Eggs/Nest	% of Eggs Giving Fledgings	Broods/year
Goldenwinged warbler, Vermivora chrysoptena																		0.1				
Tennessee warbler, Vermivora peregrina																		1.9				
Nashville warbler, Vermivora ruficapilla																		0.7				
Magnolia warbler, Dendroica magnolia																		0.6				
Yellow rumped warbler																		0.6				
Black-throated green warbler, Dendroica virens																		0.4				
Blackburian warbler, Dendroica fusca																		0.3				
Yellow-throated warbler, Dendrocia dominica																		0.3				
Blackpoll warbler, Dendroica striato																		0.6				
Palm warbler, Dendroica palmarum																		0.9				
Ovenbird, Seiurus durocapillus																		0.1				
Northern waterthrush, Seiurus noveboracensis																		1.2				
Northern oriole																		0.4				
Rose-breasted grosbeak, Pheucticus ludovicians																		0.4				

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†This information was obtained from Graber, J.W., and R.R. Graber. Environmental Evaluations using Birds and Their Habitats. Biological Notes No. 97, Illinois Natural History Survey, Urbana, Illinois, 1976 and a personal communication from the authors of this paper. In this table "S" signifies that this avian species can be found in this habitat in the summer. A "W" indicates that this species can be found in this habitat in the winter, and "S*" indicates that this species nests in this habitat.

TABLE A-IV-18. PERCENTAGE OF TOTAL COUNT OF SPECIES MAKING UP APPROXIMATELY 85 PERCENT OF BIRDS COUNTED IN THE SUMMER IN SOUTHERN ILLINOIS*

Species	Mixed hayfields[a]	Red clover fields[a]	Shrub-grown areas[a]	Ochards[b]	Woodlands with understory[b]	Urban residential areas[c]
Meadow lark	54	22	-	2	-	-
Common grackle	16	5	-	13	-	-
Bobwhite	8	-	-	2	-	-
Barn swallow	5	-	-	4	-	-
Dickcissel	5	11	-	2	-	-
Grasshopper sparrow	5	-	-	-	-	-
Redwing blackbird	-	30	4	8	-	-
Mourning dove	-	17	4	11	1	-
Indigo bunting	-	-	17	3	7	-
Field sparrow	-	-	14	6	2	-
Yellow-breasted chat	-	-	7	-	1	-
Brown-headed cowbird	-	-	7	-	3	-
Cardinal	-	-	6	5	10	-
Rufous-sided towhee	-	-	4	-	3	-
Yellowthroat	-	-	4	-	-	-
Tufted titmouse	-	-	3	-	9	-
Chickadee	-	-	3	-	5	-
Orchard oriole	-	-	3	-	-	-
American goldfinch	-	-	2	2	1	-
Carolina wren	-		2	-	4	-
Prairie warbler	-	-	2	-	-	-
Wood thrush	-	-	2	-	2	-
Bell's vireo	-	-	1	-	-	-
House sparrow	-	-	-	16	-	34
Starling	-	-	-	8	-	23
Brown thrasher	-	-	-	3	-	-
Acadian flycatcher	-	-	-	-	7	-
Kentucky warbler	-	-	-	-	4	-
Blue-gray warbler	-	-	-	-	4	-
Red-eyed vireo	-	-	-	-	3	-
White-eyed vireo	-	-	-	-	3	-
Eastern wood pewee	-	-	-	-	2	-
Common crow	-	-	-	-	2	-
Red-bellied woodpecker	-	-	-	-	2	-
Summer tanager	-	-	-	-	2	-
Worm-eating warbler	-	-	-	-	2	-
Downy woodpecker	-	-	-	-	2	-
Ceulean warbler	-	-	-	-	1	-
Yellow-throated vireo	-	-	-	-	1	-
Blue jay	-	-	-	-	1	-
American redstart	-	-	-	-	1	-
Robin	-	-	-	-	-	-
Purple martin	-	-	-	-	-	13
Rock dove	-	-	-	-	-	5
Chimney swift	-	-	-	-	-	5
Catbird	-	-	-	-	-	3
	-	-	-	-	-	3
TOTAL PERCENT	93	85	85	85	85	86
Number of Species	6	5	17	14	27	7

[a] Census taken in the summer of 1957

[b] Census taken in the summer of 1957 and summer of 1958

[c] Census taken in the summer of 1958

[*] Graber, R.R., and J.W. Graber. A Comparative Study of Bird Populations in Illinois, 1906-1909 and 1956-1958. Illinois National History Survey Bulletin, 28(3):383-528, 1963.

TABLE A-IV-19. MAMMALIAN SPECIES WHICH MAY OCCUR IN OR NEAR WHITE COUNTY, ILLINOIS*

Common Name	Scientific Name	Preferred Habitat
Opossum	*Didelphis marsupialis*	Wooded areas. Forage at water's edge and along drainage ditches. Travel along streams, ditches and fencerows.
Eastern Mole	*Scalopus aquaticus*	Wherever soil is not excessively coarse or wet.
Masked Shrew	*Sorex cinereus*	Overgrown fields and mature woodlands.
Southeastern Shrew	*Sorex longirostris*	Dense grasses and sedges. Forage along small streams and edges of marshes.
Least Shrew	*Cryptotis parva*	Brushy, overgrown fields and fencerows.
Shorttail Shrew	*Blarina brevicauda*	Heavy ground cover in woods, open fields and marsh areas.
Little Brown Myotis	*Myotis lucifugus*	Hollow trees, caves and buildings.
Indiana Myotis	*Myotis sodalis*	Wooded areas, streams and ponds.
Keen Myotis	*Myotis keeni*	Caves, near streams and ponds.
Silver-Haired Bat	*Lasionycteris noctivagans*	Borders of wooded areas near ponds.
Eastern Pipistrel	*Pipistrellus subflavus*	Caves and trees.
Big Brown Bat	*Eptesicus fuscus*	Woodlands.
Evening Bat	*Nycticeius humeralis*	Woodlands and ponds.
Red Bat	*Lasiurus borealis*	Wooded and brushy areas.
Hoary Bat	*Lasiurus cinereus*	Wooded areas.
Raccoon	*Procyon lotor*	All habitats near water.
Longtail Weasel	*Mustela frenata*	Woodlands and overgrown fields near water.
Mink	*Mustela vison*	Woodlands near streams and lakes.
River Otter	*Lutra canadensis*	Along streams and lakes.
Striped Skunk	*Mephitis mephitis*	Fencerows, overgrown fields and stream borders.
Red Fox	*Vulpes fulva*	Open, dry areas.
Gray Fox	*Urocyon argenteus cinereo*	Brushy and wooded areas.
Coyote	*Canis latrans*	Brushy portions of farmlands.
Woodchuck	*Marmota monax*	Woodlands, open woodlots, fencerows, railroad beds and pastures.
Thirteen Striped Ground Squirrel	*Citellus tridecemlineatus*	Open grassland.

(continued)

TABLE A-IV-19. (continued)

Common Name	Scientific Name	Preferred Habitat
Eastern Chipmunk	*Tamias striatus*	Overgrown fields, fencerows, open woods and woodlots with heavy understory.
Red Squirrel	*Tamiasciurus hudsonicus*	Woodlands.
Eastern Gray Squirrel	*Sciurus carolinenomeasis*	Wooded areas with good understory interspersed with overgrown fields.
Eastern Fox Squirrel	*Sciurus niger*	Open woods, woodlots, windbreaks and wooded fencerows.
Southern Flying Squirrel	*Glaucomys volans*	Mature wooded areas.
Beaver	*Castor canadensis*	Wooded stream and lake shores.
Prairie Deer Mouse	*Peromyscus maniculatus bairdi*	Dry open grasslands.
Woodland Deer Mouse	*Peromyscus maniculatus graeilis*	Wooded areas.
White-Footed Mouse	*Peromyscus levcopus*	Marsh borders, fencerows and woodlands.
Eastern Woodrat	*Neotoma magister*	Rocky areas.
Southern Bog Lemming	*Synaptomys cooperi*	Damp grassy meadows.
Meadow Vole	*Microtus pennsylvanicus*	Moist areas supporting dense grasses, fencerows, woodlot borders and stream banks.
Prairie Vole	*Pedomys ochrogaster*	Dry, fallow fields with good cover.
Pine Vole	*Pitymus pinetorum*	Mature wooded areas.
Muskrat	*Ondatra zibethica*	Bodies of water with heavy growth of cattails or bushes.
Norway Rat	*Rattus norvegicus*	Human habitations.
Meadow Jumping Mouse	*Zapus hudsonius*	Damp meadows.
Woodland Jumping Mouse	*Napaeozapus insignis*	Forests bordering lakes and streams.
Eastern Cottontail	*Sylvilagus floridanus*	Overgrown fields and other areas with dense ground cover.
White Tail Deer	*Odocoileus virginianus*	Brushy areas, woodlands and woodland borders.
Swamp Rabbit	*Sylvilagus aquaticus*	Near cane stands in dense woods or brush which is seasonally flooded.
House Mouse	*Mus musculus*	Human habitations.

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*Beck, R.W. and Associates. Environmental Analysis Merom Generating Station for Hoosier Energy Division of Indiana Statewide R.E.C., Inc., 1976.

TABLE A-IV-20. SMALL GAME HUNTING IN WHITE COUNTY AS COMPARED TO THE REST OF THE STATE**

Animal	Mean number harvested annually (in 100's)[a]	Percentage of total Illinois harvest[a]	Mean number hunter-trips annually (in 100's)[a]	Percentage of total Illinois hunter-trips[a]	Kills per hunter-trip White County	Kills per hunter-trip statewide[b]	Total killed statewide 1956-1969
Dove	142	0.9	32	0.7	4.44	3.56 (1956:3.36 to 1968:3.95)	Increased
Pheasant	*		*			0.82 (1967:0.57 to 1963:0.99)	Fluctuates
Bobwhite	303	1.4	92	1.2	3.29	2.75 (1960:2.32 to 1958:3.34)	Fluctuates
Gray & fox squirrel	255	0.9	127	0.9	2.01	2.00 (1958:1.85 to 1957:2.22)	ca. unchanged
Cottontails	275	0.7	116	0.6	2.37	1.83 (1965:1.38 to 1958:2.38)	Decreased 1956-1965 ca. Unchanged 1966-1969
Combined	975	0.7	367	0.7	2.66	1.98 (1965:1.70 to 1958:2.21)	Decreased 1956-1960 ca. Unchanged 1960-1969

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[*] Less than 50 cock pheasants were shot annually in the county with less than 50 hunter-trips.

[**] Preno, W.L. and R.F. Labisky. Abundance and Harvest of Doves, Pheasants, Bobwhites, Squirrels, and Cottontails in Illinois, 1956-1969. Technical Bulletin Number 4, State of Illinois Department of Conservation, Springfield, Illinois, 1971.

[a] During 1956-1969, the arithmetic average by county percentage of Illinois combined total harvest is 1.0 (std. dev. = 0.5 range: 0.2 for Boone County to 2.5 for Madison County) for the 102 Illinois counties. Average percentage of Illinois combined total hunter-trips per county is 1.0 (std. dev. 0.5, range 0.3 for Hardin and Henderson Counties to 2.3 for Will County).

[b] Arithmetic mean (range).

TABLE A-IV-21. RARE AND ENDANGERED SPECIES THAT MAY OCCUR IN OR NEAR WHITE COUNTY, ILLINOIS**

Plants (A,B)

Plant species that are federally endangered (*) or threatened that occur in Illinois.

*_Apios priceana_ Robins. - Price's Potato Bean

*_Asclepias meadii_ Torr. - Mead's Milkweed

Astragalus tennesseensis Gary - Milk Vetch

Boltonia asteroides var. decurrens (Torr. & Gray) Engelm. - False Aster

Carex socialis Mohlenbr. & Schwegm.

Cirsium pitcheri (Torr.) Torr. & Gray - Dune Thistle

Cladrastis lutea (Michx. F.) K. Koch - Yellow-wood

*_Cyperus grayioides_ Mohlenbr.

Cypripedium candidum Muhl. - White Lady's-slipper orchid

Dodecatheon frenchii (Vasey) Rydb. - French's shooting-star

Hydrastis canadensis L. - Goldenseal

*_Iliamna remota_ Greene - Kankakee Mallow

*_Isotria medeoloides_ (Pursh) Raf. - Small Whorled Pogonia

*_Lespedeza leptostachya_ Engelm. - Prairie Bush-clover

Panax quinquefolius L. - Ginseng

*_Petalostemum foliosum_ Gray - Leafy Prairie Clover

*_Plantago cordata_ Lam. - Heart-Leaf Plantain

Platanthera (Habenaria) flava - Tubercled Orchid

Platanthera (Habenaria) leucophaea - White Fringed Orchid

Platanthera (Habenaria) peramoena - Purple Fringeless Orchid

(continued)

TABLE A-IV-21. (continued)

Sullivantia renifolia Rosend. - Sullivantia

Synandra hispidula (Michx.) Baill. - Synandra

**Thismia americana* N.E. Pfeiffer

Plant species that have not been collected in Illinois in 50 or more years, or were known from only a few sites which have been destroyed or altered and are apparently extirpated from the state.

Andromeda glaucophylla Link. - Bog Rosemary

Arabis drummondii Gray - Rock Cress

Arethusa bulbosa L. - Dragon's Mouth

Asplenium ruta-muraria L. - Wall-rue Spleenwort

Bergia texana (Hook.) Seubert

Chamaesyce vermiculata (Raf.) House - Spurge

Corallorhiza trifida Chat. - Pale Coral-root Orchid

Delphinium virescens Nutt. - Prairie Larkspur

Elatine brachysperma Gray - Waterwort

Eleocharis caribaea (Rottb.) Blake - Spike Rush

Eleocharis equisetoides (Ell.) Torr. - Horsetail Spike Rush

Epigaea repens L. - Trailing Arbutus

Equisetum scirpoides Michx. - Dwarf Scouring Rush

Erianthus brevibarbis Michx. - Brown Plume Grass

Eriophorum gracile Koch. - Cotton Sedge

Eriophorum tennellum Nutt. - Cotton Sedge

Gaura filipes Spach. - Slender Gaura

Gratiola aurea Muhl. - Goldenpert

(continued)

TABLE A-IV-21. (continued)

Habenaria blephariglottis (Willd.) Hook. - White Fringed Orchid

Habenaria dilatata (Pursh.) Hook. - Round-leaved Orchid

Isoetes engelmannii A. Br. - Engelmann's Quillwort

Linnaea americana Forbes - Twinflower

Malaxis monophylla (L.) Sw. - Adder's Mouth Orchid

Malaxis unifolia Michx. - Adder's Mouth Orchid

Oenothera missouriensis Sims. - Missouri Primrose

Oryzopsis asperifolia Michx. - Rice Grass

Oryzopsis pungens (Torr.) Hitchcock - Rice Grass

Paspalum dissectum (L.) L. - Bead Grass

Pinus banksiana Lamb. - Jack Pine

Poa paludigena Fern. & Wieg. - Marsh Bluegrass

Polygala paucifolia Willd. - Flowering Wintergreen

Polygonum arifolium L. - Tear Thumb

Potentilla tridentata Ait. - Three-toothed Cinquefoil

Rhynchospora globularis (Chapm.) Small - Beaked Rush

Rumex hastatulus Baldw. - Sour Dock

Sabatia campestris Nutt. - Prairie Rose Gentian

Schedonnardus paniculatus (Nutt.) Trel. - Tumble Grass

Scirpus subterminalis Torr. - Bulrush

Scirpus torreyi Olney - Bulrush

Sparganium minimum (Hartm.) Fries. - Least Bur-reed

Trautvetteria caroliniensis (Walt.) Vail. - False Bugbane

Trillium cernuum L. - Nodding Trillium

(continued)

TABLE A-IV-21. (continued)

Valerianella intermedia Dyal. - Corn Salad

Valerianella patellaria (Sulliv.) Wood - Corn Salad

Valerianella umbilicata (Sulliv.) Wood - Corn Salad

Vernonia arkansana DC. - Ironweed

Xyris jupicai L. Rich. - Yellow-eyed Grass

Plant species that are represented by disjunct or relict populations in Illinois

Aristida desmantha Trin. & Rupr. - Three-awn Grass

Aster schreberi Nees. - Schreber's Aster

Camassia angusta (Engelm. & Gray) Blankinship - Wild Hyacinth

Chimaphila maculata (L.) Pursh. - Spotted Wintergreen

Gymnocarpium dryopteris (L.) Newm. - Oak Fern

Hudsonia tomentosa Nutt. - Beach Heath

Lesquerella ludoviciana (Nutt.) S. Wats. - Silvery Bladder Pod

Lycopodium clavatum L. - Running Pine

Lycopodium dendroideum Michx. - Ground Pine

Pinus resinosa Ait. - Red Pine

Schizachne purpurascens (Torr.) Swallen. - False Melic Grass

Schrankia uncinata Willd. - Cat-claw

Scirpus hallii Gray - Bulrush

Sorbus americana Marsh. - Mountain Ash

Spiranthes lucida (H.H. Eaton) Ames - Yellow-lipped Ladies' Tresses

Stylisma pickeringii (Torr.) Gray - Patterson Bindweed

(continued)

TABLE A-IV-21. (continued)

Thuja occidentalis L. - Arbor Vitae

Waldsteinia fragarioides (Michx.) Tratt. - Barren Strawberry

Woodsia ilvensis (L.) R. Br. - Rusty Woodsia

Plant species that are restricted to a specialized and limited habitat in Illinois

Amelanchier humilis Wieg. - Low Shadbush

Ammannia auriculata Willd. - Scarlet Lousestrife

Ammophila breviligulata Fern. - Beach Grass

Arenaria patula Michx. - Slender Sandwort

Aronia prunifolia (Marsh.) Rehd. - Purple Chokeberry

Asplenium bradleyi D.C. Eaton - Bradley's Spleenwort

Aster furcatus Burgess. - Forked Aster

Aster junciformis Rydb. - Rush Aster

Baptisia tinctoria (L.) R. Br. - Yellow Wild Indigo

Bartonia paniculata (Michx.) Muhl. - Screw-stem

Bartonia virginica (L.) BSP. - Yellow Bartonia

Betula pumila L. - Dwarf Birch

Buchnera americana L. - Blue Hearts

Cakile edentula (Bigel.) Hook - Sea Rocket

Ceanothus ovatus Des. F. - Red-root

Chamaesyce polygonifolia (L.) Small - Seaside Spurge

Cladium mariscoides (Muhl.) Torr. - Twig Rush

Corispermum hyssopifolium L. - Common Bugseed

Corydalis sempervirens (L.) Pers. - Pink Corydalis

(continued)

TABLE A-IV-21. (continued)

Cypripedium calceolus L. *var. parviflorum* (Salisb.) Fern - Small yellow Lady's-Slipper Orchid

Deschampsia cespitosa (L.) Beauv. - Tufted Hairgrass

Dirca palustris L. - Leatherwood

Dodecatheon amethystinum Fassett - Jeweled Shooting-star

Drosera intermedia Hayne. - Narrow-leaved Sundew

Drosera rotundifolia L. - Round-leaved Sundew

Eleocharis olivacea Torr. - Spike Rush

Eleocharis rostellata (Torr.) Torr. - Spike Rush

Eleocharis wolfii (Gray) Patterson - Spike Rush

Epilobium leptophyllum Raf. - Bog Willow Herb

Epilobium strictum Muhl. - Downy Willow Herb

Eriophorum viridi-carinatum (Engelm.) Fern. - Cotton Sedge

Eriophorum virginicum L. - Cotton Sedge

Filipendula rubra (Hill) Robins. - Queen-of-the-prairie

Gaultheria procumbens L. - Wintergreen

Gentiana crinita Froel. - Fringed Gentian

Gentiana procera Holm. - Small Fringed Gentian

Gerardia pedicularia L. - Clammy False Foxglove

Habenaria hyperborea (L.) R. Br. - Green Orchid

Habenaria lacera (Michx.) Lodd. - Green Fringed Orchid

Hymenopappus scabiosaeus L'Her.

Hymenoxys acaulis (Pursh) Parker - Lakeside Daisy

Lathyrus maritimus (L.) Bigel. - Beach Pea

Lycopodium inundatum L. - Bog Clubmoss

(continued)

TABLE A-IV-21. (continued)

Lycopodium lucidulum Michx. - Shining Clubmoss

Lycopodium porophilum Lloyd & Underw. - Cliff Clubmoss

Mimulus glabratus HBK - Yellow Monkey-Flower

Oryzopsis racemosa (J.E. Smith) Ricker. - Rice Grass

Panicum ravenelii Scribn. & Merr. - Ravenel's Panic Grass

Parnassia glauca Raf. - Grass-of-Parnassus

Pogonia ophioglossoides (L.) Ker. - Snake-mouth

Potentilla fruticosa L. - Shrubby Cinquefoil

Rhamnus alnifolia L'Her. - Alder Buckthorn

Rhynchospora alba (L.) Vahl. - Beaked Rush

Rhynchospora capillacea Torr. - Beaked Rush

Rhynchospora glomerata (L.) Vahl. - Beaked Rush

Rhyncospora macrostrachya Torr. - Beaked Rush

Ribes hirtellum Michx. - Northern Gooseberry

Ruppia maritima L. - Ditch grass

Salix candida Fluegge - Hoary Willow

Salix pedicellaris Pursh. - Bog Willow

Sanguisorba canadensis L. - American Burnet

Sarracenia purpurea L. - Pitcher-plant

Saxifraga forbesii Vasey - Forbe's Saxifrage

Scheuchzeria palustris L. - Arrow-grass

Scleria reticularis Michx. - Nut Rush

Scleria verticillata Muhl. - Nut Rush

Selaginella apoda (L.) Fern. - Small Spikemoss

(continued)

TABLE A-IV-21. (continued)

Selaginella rupestris (L.) Spring - Rock Spikemoss

Thelypteris noveboracensis (L.) Nieuwl. - New York Fern

Trichomanes boschianum Sturm. - Filmy Fern

Trichostema dichotomum L. - Blue Curls

Triglochin maritima L. Arrow-grass

Triglochin palustris L. - Arrow-grass

Tofieldia glutinosa (Michx.) Pers. - False Asphodel

Ulmus thomasii Sarg. - Rock Elm

Viburnum molle Michx. - Arrowwood

Woodwardia virginica (L.) Sm. - Chain Fern

Xyris torta Sm. - Twisted Yellow-eyed Grass

Zigadenus glaucus Nutt. - White Camass

Plant species that are scattered throughout Illinois but are not common

Brasenia schreberi Gmel. - Watershield

Cyperus engelmannii Steud.

Eleocharis quadrangulata (Michx.) Roem. & Schultes. Square-stemmed Spike Rush

Elymus riparius Wiegand. - Wild Rye

Isoetes melanopoda Gay & Dur. - Black Quillwort

Medeola virginiana L. - Indian Cucumber Root

Monotropa hypopithys L. - Pinesap

Polygala incarnata L. - Pink Milkwort

Polytaenia nuttallii DC - Prairie Parsley

Sagittaria cuneata Sheld. - Arrow leaf

(continued)

TABLE A-IV-21. (continued)

Scirpus polyphyllus Vahl. - Bulrush

Scirpus purshianus Fern. - Bulrush

Sparganium androcladum (Engelm.) Morong-Bur-reed

Sparganium chlorocarpum Rydb. - Green-fruited Bur-reed

Talinum rugospermum Holz. - Fameflower

Thelypteris phegopteris (L.) Slosson - Long Beech Fern

Trifolium reflexum L. - Buffalo Clover

Veratrum woodii Robbins. - False Hellebore

Wulfenia bullii (Eat.) Barnh. - Kitten Tails

Clams and Mussels

Fat Pocketbook Pearly Mussel, *Potamilus* (*Proptera*) *capax*

This species has been listed as an endangered species by the Secretary of the Interior in accordance with provisions of the Endangered Species Act of 1973. A fresh shell of this species was found in the Wabash River at Vincennes, Indiana, on September 20, 1961 (C).

Tuberculed-Blossom Pearly Mussel, *Epioblasma* (*Dysnomia*) *torulosa torulosa*

This species has been listed as an endangered species by the Secretary of the Interior in accordance with provisions of the Endangered Species Act of 1973. This species may be found in the Wabash River downstream from Terre Haute, Indiana (C).

Rough Pigtoe Pearly Mussel, *Pleurobema plenum*

This species has been listed as an endangered species by the Secretary of the Interior in accordance with the provisions of the Endangered Species Act of 1973. This species may be found in the Wabash River downstream from Terre Haute, Indiana (C).

(continued)

TABLE A-IV-21. (continued)

Blue-Point, Amblema peruviana (Lamarck)

This species was previously found in the White and Wabash Rivers; however, the survey of Krumholz and coworkers failed to find any specimens left in 1969 (D).

Spike, Lady Finger, Elliptio dilatatus (Rafinesque)

This species was once common throughout Indiana Rivers; however, the 1969 survey of Krumholz and coworkers of the White and Wabash Rivers uncovered only isolated dead shells of this species (D).

Rabbit's Foot, Quadrula cylindrica (Say)

This species was once common throughout the rivers of Indiana; however, the survey of Krumholz and coworkers found only dead shells of this species in 1969 (D).

Pleurobema cordatum (Rafinesque)

This species is much less abundant and has a much more restricted patterns of distribution in the White and Wabash Rivers than recorded prior to 1969 (D).

Purple Warty Back, Cyclonaias tuberculata (Rafinesque)

This species is much less abundant and has a much more restricted pattern of distribution than recorded prior to 1969 for the White and Wabash Rivers (D).

Fan-Shell, Cyprogenia irrorata (Lea)

This species is much less abundant and has a more restricted distribution in the Wabash and White Rivers than recorded prior to 1969 (D).

Obovaria subrotunda (Rafinesque)

This species is much less abundant and has a much more restricted pattern of distribution than recorded prior to 1969 (D).

Bullhead, Sheepnose; Plethobasus cyphyus (Rafinesque)

In Illinois the Bullhead is restricted primarily to the Mississippi River above St. Louis and in the lower Wabash and Ohio Rivers. It is usually found in current on a mud bottom at

(continued)

depths of 90-180 cm, although this large river species may live at much greater depths (E).

This species may be found in the Little Wabash and Vermilion Rivers in eastern Illinois. Although this species may be locally numerous in parts of its range, *Carunculina glans* is apparently uncommon to rare in Illinois and restricted to tributaries of the Wabash and Ohio Rivers. It may be found on mud, but this mussel has been reported as thriving best on sand or fine gravel beds, in shallow running water (E).

Carunculina texasensis (Lea)

This is the largest and most sporadic in distribution of the three species of *Carunculina* found in Illinois. This species has apparently been taken at only three localities: North Fork, Saline River (Galatin Co.), and in the Big Muddy River and Crab Orchard Lake (Williamson Co.). At Crab Orchard Lake, this mussel was very numerous in several areas, living on a soft mud bottom in 30-60 cm. of water; the largest specimens measured 5.7 cm. in length (E).

Fan-Shell, *Cyprogenia irrorata* (Lea)

This attractive mussel is now restricted to the lower Wabash River in Illinois where it is relatively uncommon to rare. Shells recovered from Indian middens along the banks of the Ohio River in the southeastern part of the state attest to its former occurrence in that stretch of the river, but recent collections have failed to recover living specimens. In the Wabash River in Illinois, this species has been found living on a coarse sand and gravel bottom, in current, and at depths of a few centimeters to 60 cm. (E).

Dysnomia perplexa (Lea)

Presently *Dysnomia perplexa* is an uncommon or rare mussel in Illinois, occurring rather sporadically in the lower Wabash and Ohio Rivers. Although typically a small species, shells collected by mussel fishermen in the Ohio River near Metropolis are large and measure 8 cm. in length. It is usually found in a coarse sand and gravel bottom, in current and at depths varying from 8 to 180 cm. (E).

(continued)

TABLE A-IV-21. (continued)

Pink Mucket Pearly Mussel, Lampsilis orbiculata orbiculata

This mussel is limited in its habitat to large rivers, and in Illinois it occurs in the Ohio River and the lower Wabash River downstream from Terre Haute, Indiana. Apparently little is known concerning typical depths and bottom types in which this species occurs except that it is taken by mussel fishermen usually in deep water. Lampsilis orbiculata is an uncommon to rare mussel in Illinois. This species has been listed as an endangered species by the Secretary of the Interior in accordance with the provisions of the Endangered Species Act of 1973 (C,E).

Butterfly, Plagiola lineolata (Rafinesque)

One of the most attractive mussels found in Illinois, the Butterfly occurs primarily in the lower Wabash, Ohio and Mississippi Rivers. It is only moderately common, living on a sand or gravel bottom, especially on bars, in current at depths of 180 cm. or more. Plagiola is apparently less tolerant of silting and pollution than many species; it was once fairly common and widespread in the Illinois River, but has now completely disappeared as a result of these factors. Uniform thickness of shell, and good color and luster of the nacre made the Butterfly a valuable button shell (E).

Kidney-Shell, Ptychobranchus fasciolaris (Rafinesque)

This mussel typically inhabits small to medium-sized rivers, although it may become established in large rivers in sections (riffles) or normally shallow water. In Illinois, it is now apparently confined to the lower Wabash River where it is an uncommon to rare mussel. Specimens of Ptychobranchus attain maximum size (11 to 13 cm. in length) and thickness in the larger rivers. A few individuals collected recently in the Wabash River were taken on a coarse sand and gravel bottom, in current and at a depth of 60-90 cm. of water (E).

Fusconaia subrotunda (La).

This large river species was once (1944) found in the Ohio and its tributaries, and in larger portions of the Wabash River. It may still be of rare occurrence in these rivers (E).

(continued)

TABLE A-IV-21. (continued)

Lastena lata (Rafinesque)

In 1944 this species was found in the Ohio and Wabash Rivers. It is a rare shell throughout its range. The shell is thin but fairly strong, greatly elongated, and compressed (E).

White Warty-Back Pearly Mussel, *Plethobasis cicatricosus* (Say)

This species has been listed as an endangered species by the Secretary of the Interior in accordance with provisions of the Endangered Species Act of 1973. This species may be found in the Wabash River downstream from Terre Haute, Indiana (C).

Orange-Footed Pimpleback, *Plethobasis cooperianus* (Say)

This species has been listed as an endangered species by the Secretary of the Interior in accordance with provisions of the Endangered Species Act of 1973. This species may be found in the Wabash River downstream from Terre Haute, Indiana (C).

Pleurobema clava (Lamark)

Mature specimens rarely exceed 8 cm. in length (E).

Simpsoniconcha ambigua (Say)

This species has been found in the Wabash River, but it is very sporadic in distribution (E).

Dysnomia foliata Hildreth

The shell is heavy, solid and somewhat compressed. It is generally squarish in outline in the male and "leaf-like" in the female (E).

White Cat's Paw Pearly Mussel
Epioblasma (Dysnomia) sulcata delicata

Epioblasma (Dysnomia) sulcata delicata has been listed as an endangered species by the Secretary of the Interior in accordance with the provisions of the Endangered Species Act of 1973. This species may be found in the Wabash River downstream from Terre Haute, Indiana (C).

A very closely related species, *Dysnomia personata* (Say), which might be considered only a transition form between *Dysnomia foliatus* and *Dysnomia sulcata* occurs (rarely) in the

(continued)

TABLE A-IV-21. (continued)

lower Wabash River. It very closely resembles - and is nearly inseparable from - Dysnomia sulcata (E).

Sampson's Pearly Mussel, Epioblasma (Dysnomia) sampsoni

The shell of this species has the posterior ridge sharply angled, the row of knobs high, and the umbones large and greatly inflated and elevated well beyond the hinge line. Dysnomia sampsoni may be a large river form or variant of Dysnomia perlexa (E).

This species of mussel was listed as endangered by the Secretary of the Interior in accordance with the provisions of the Endangered Species Act of 1973. Its known range includes that portion of the Wabash River which forms the common boundary between the states of Illinois and Indiana (C).

Leptodea blatchleyi (Daniels)

This species has been found only at "Grand Chains," Wabash River, Posey Co., Indiana (E).

Villosa (= Micromya) fabalis (Lea)

The Wabash River is the only known locality for this species in Illinois (E).

Obovaria retusa (Lamarck)

In Illinois this large river species has been reported from the Wabash and Ohio Rivers (E).

Fish

Bigeye Chub, Hybopsis amblops (Rafinesque)

The Bigeye Chub is a member of the minnow family. At present the Bigeye Chub can be found in the Middle Fork and the Salt Fork of the Vermilion River in Vermilion County. It has also been found recently (post 1950) in the Little Wabash River and in a tributary to the Embarras River. Prior to 1905, it was abundant throughout eastern and southern Illinois. It is extirpated or decimated in parts of its range, but it is common in other parts. In the state of Illinois it is considered endangered and possibly extinct. The reasons for its decline are thought to be siltation, turbidity, and lack of aquatic vegetation (F,G).

(continued)

TABLE A-IV-21. (continued)

A proposal has been made to place this species on the endangered species list of the Illinois Fish Code and prohibit by law taking of this species. Management recommendations include purchase of the streams, where the fish is presently found, as state-owned property and improve the habitat to enhance the species (F).

Ohio Lamprey, Ichthyomyzon bdellium (Jordan)

The Ohio Lamprey has apparently been extirpated from the Wabash and Ohio drainage systems (H). This species has not been collected in Illinois since 1917 (H). Extirpation of species of lamprey is not considered environmentally damaging in most circles.

River Chub, Hybopsis gilidxa

The River Chub is only known from the Wabash River in Lawrence and Clark Counties (G).

River Redhorse, Moxostoma carinatum

Rare in Illinois and most parts of its range, the River Redhorse has declined due to siltation, pollution, and deterioration of preferred habitat. It is presently found in eastern Illinois in the Vermilion and Fox River systems (G).

Northern Madtom, Noturus stigmosus Taylor

This member of the catfish family reaches a maximum length of about 10 cm. It is found at one locality in the Lower Vermilion River and one in the Wabash River (in Wabash County). Its former range is similar to its present range. Throughout the United States this fish is rare in some parts of its range and common in other parts. This species has always been rare in Illinois, and there is no evidence of a recent decline. The fecundity of this species is not known (F).

It has been proposed to place this species on the endangered species list of the Illinois Fish Code and to prohibit taking this species. Management recommendations include acquisition of streams where most abundant and improvement of the habitat for the species (F).

(continued)

Banded Pygmy Sunfish, Elassoma zonatum Jordan

This sunfish reaches a length of about 3.8 cm. The sunfish is sexually mature at one year and spawns annually. The number of eggs produced is not known (F).

At present, this sunfish is found in Illinois in swamps in Union and Johnson Counties. Its former range included these swamps and swamps in the Wabash Valley and in White County. The fish seems to have disappeared from these latter two locations due to drainage of the swamps and oil field pollution in White County. This species is rare in the northern part of its range but common on the Gulf Coast; indication that restocking of the sunfish in swamps in manmade impoundments or natural swamps in White County may be feasible (F).

The sunfish is presently protected in the Illinois Fish Code as an endangered species. The habitat of this species is under protection of the Forrest Service and the Nature Conservatory; thus, they are out of immediate danger (F).

Bluebreast Darter, Etheostoma camurum (Cope)

The present distribution of this species in Illinois is a 19-km stretch of the Middle Fork of the Vermilion River in Vermilion County. Previously, it was also found in the Salt Fork of the Vermilion River in Vermilion County. The reason for the decline of this species is listed as pollution. The occurrence of this fish is sporadic throughout its range in the United States. It is considered rare and endangered in Illinois (F).

At present, this species is protected by the Illinois Fish Code as an endangered species. Management recommendations include acquisition of the stream where the species is located and improvement of the habitat (F).

Harlequin darter, Etheostoma histrio Jordan and Gilbert

The Harlequin darter attains a length of 6.4 cm. It reaches sexual maturity at one year and spawns annually. The number of eggs that it produces is not known (F).

(continued)

TABLE A-IV-21. (continued)

The present distribution is a 16-km stretch of the Embarras River in Cumberland and Jasper Counties. Its former range corresponds to its present range. This fish has always been rare; there is no evidence of a recent decline. The occurrence of this fish in the United States is sporadic throughout its range (F).

This fish is considered rare in Illinois. It is protected by the Illinois Fish Code as an endangered species. Management recommendations include acquisition of the stream where the species occurs and improvement of the habitat (F).

Pugnose Minnow, Notropis emiliae

The pugnose minnow was formerly found in the Wabash River and its tributaries in and near White County. This species requires clear water and has been decimated in these locations primarily due to the disappearance of aquatic vegetation due to siltation (I).

Bigeye Shiner, Notropis boops Gilbert

The Bigeye Shiner reaches a maximum length of about 8 cm. The shiner reaches sexual maturity at one year and spawns annually. The number of eggs produced is not known (F).

At present, this species is considered rare in Illinois with a few populations in the southwestern and east-central parts of the state and in Grundy County. Recent records (post-1950) show the species to be present in the Little Wabash and the Little Vermilion Rivers. Prior to 1905, the species was widespread and abundant in the Vermilion River system. It is considered rare in some parts of its range but is abundant in the Ozarks. The reasons for the decline of this species are thought to be siltation, turbidity, and disappearance of aquatic vegetation (F,I).

At present, no measures have been taken to protect this species. A proposal has been made to place this species on the endangered species list of the Illinois Fish Code and to prohibit taking of this species. Proposed management recommendations include the purchase of streams where the species is most abundant and improvement of the habitat and watershed (F).

(continued)

Reptiles

Alligator Snapping Turtle, *Macrochelys temmincki*

The Alligator Snapper is the largest turtle inhabiting Illinois waters. The largest snapper may attain a weight of over 90 kg and possess a carapace measuring more than 60 cm in length (J).

This species is known to inhabit large permanent rivers and their tributaries, swamps, streams, sloughs and canals, preferring the deep, muddy-bottomed sections in which to seek protection and to lie in wait for prey. There is a remarkable structure on the tongue that serves as a lure for prey. It is a cylindrical, pinkish, worm-like growth that can be moved whenever the snapper wishes. The turtle, resting motionless on the bottom with its mouth held open, moves this structure giving it the appearance of a wriggling worm, and thus attracting the fish (its principal food) to the waiting jaws. On land it is awkward and slow-moving. In Illinois this species can be considered endangered and only a very few specimens have been taken. This may be due, in part at least, to its relatively secretive habits; however, some consider pollution to be wiping out this species (G,J).

Little is known of the breeding habits of this species in Illinois. In the southern extremes of the range, the eggs, averaging about 20 in number (range 15 to 50), are laid during April, May, or June, and hatching occurs about three and one-half months later. Little is known of their rate of growth; length of life in captive specimens has been recorded as 65 years, although it is thought that they may live to considerably older than this (J).

The Alligator Snapper occurs in the Mississippi, lower Illinois, Ohio, and Wabash Rivers and their associated tributaries and may occur in swamps and streams throughout the southern fifth of the state (J).

At least one specimen of this species has been taken from White County (G,L).

(continued)

TABLE A-IV-21. (continued)

Common Mud Turtle, Kinosternon subrubrum

This is another small species of turtle, the carapace of adults averaging about 7-8 cm. in length (J).

This is a rare turtle in Illinois and locality records are few. Apparently fairly shallow, muddy ditches, ponds and weedy lakes are the preferred habitats. It is not completely aquatic, and often wanders about on land a considerable distance from water. Little information is available on the food habits of this species, although they have been known to feed on small fish and a variety of insects (J).

Breeding is known to occur in early spring and egg-laying takes place from the last of March through July. Two to five eggs may be laid by a single female, although three is the usual number. The eggs are deposited in holes on the banks of ponds or in moist soil along the open edges of the water. This species is not too particular as to the exact site of the nest or in concealing it after the eggs have been deposited (J).

Common Map Turtle, Graptemys geographica

This species is a moderately large aquatic turtle (maximum carapace length of males, 13 cm.; females, 28 cm.). Large rivers, lakes and marshes that are of a permanent nature constitute the main habitat types for this species. Such bodies of water having mud bottoms and vegetation are especially preferred. In Illinois the Map Turtle is confined primarily to the large rivers, but even in such habitats it is not common. The Map Turtle feeds almost exclusively on aquatic insects, snails, mussels (fresh water clams) and crayfish. The powerful jaws are provided with broad crushing surfaces which enable the turtle to utilize such hard-shelled foods.

Mating takes place in early spring; and the eggs, 10 to 16 being the usual clutch, are laid in May, June or July. Those eggs laid early in the spring hatch during August and September, while those deposited in late spring or early summer may remain in the nest throughout the winter and then hatch the following spring. The nests are dug in soft, loose soil or sand, and may be found as far as half a kilometer from the nearest body of water.

Like many aquatic turtles, the Map Turtle enjoys sunning itself on logs and other objects in the water. Although it is an edible species, apparently it is little used by man for food (J).

False Map Turtle, Graptemys pseudogeographica

Adult males and females of this species show marked differences in size (maximum carapace length about 23 cm.). The False Map Turtle is an aquatic species and inhabits streams and rivers with considerable current, and like the Map Turtle is uncommon in most areas. It is a shy turtle and, although it spends many hours on a stranded log or protruding deadhead basking in the hot sun, it remains wary and on the alert, sliding into the water at the slightest disturbance. The food habits of this species closely parallel those of the Map Turtle, except that the False Map Turtle is somewhat more omnivorous, feeding to a greater extent (as adults) on vegetation (K).

Relatively little information is available concerning egg-laying, nesting and the incubation period of this turtle. Apparently egg-laying does not commence before July. The number of eggs laid by a female varies from 7 to 13, although 9 or 10 constitutes the usual number. Newly hatched young have been taken in August and September (K).

Hieroglyphic Turtle, Pseudemys floridana hieroglyphica

This is a moderately large turtle, having a maximum carapace length of about 38 cm. (J). Permanent bodies of water such as large, rather shallow ponds, sloughs and slow-moving rivers provide the best habitat for this species. Bodies of water possessing a mud bottom and plenty of aquatic vegetation are especially preferred. This turtle is extremely rare in Illinois, and little is known of its life history in the state. The Hieroglyphic Turtle feeds almost entirely on animal matter, especially insects, crayfish, tadpoles, small fish and carrion (J).

Almost no information is available on the breeding and nesting habits of this turtle. The few available records indicate that nesting occurs in June, and that the number of eggs laid will average 10 to 12 (J).

Hieroglyphic Turtle, Pseudemys concinna hieroglyphica x floridana hoyi

This hybrid which is also known as the hybrid slider is very rare in Illinois and is restricted to the large rivers and adjacent lakes in southern Illinois. The range extends southward from Illinois. The Hieroglyphic Turtle is only known to leave the water to bask on logs or lay eggs (J).

(continued)

TABLE A-IV-21. (continued)

Graham's Water Snake, Natrix grahami

This moderately large water snake, which averages about 60 cm. in length, is characterized by a broad yellow stripe along either side with an irregular narrow black border below (along the edges of the belly scales).

Graham's Water Snake is uncommon in Illinois. It is apparently more secretive than most of the other water snakes, and it is said to be considerably more docile than the majority of Natrix which usually possess a rather excitable disposition. Small fish, salamanders, frogs and crayfish are eaten, although crayfish seem to be the preferred food (J).

This species inhabits backwater sloughs, ponds and streams, often hiding under driftwood, brush piles along the water's edge or in crayfish burrows. The young, which average about 12 in number, are born alive in late August (J).

Red-bellied Snake, Storeria occipitomaculata

This reptile is restricted to moist areas, quite often in wood sections, and utilizes boards, logs, stones and similar objects for hiding places. It is rather uncommon in Illinois. Although the Red-bellied Snake is known to climb, most of its activity takes place on the ground where it obtains slugs which are eaten in preference to almost all other foods. The young are born usually during late July and August and average about seven in number (J).

Red Milk Snake, Lampropeltis doliata syspila

The Red Milk Snake is a fairly slender snake, having an average length of 60 cm. The Milk Snake is relatively uncommon in Illinois and shows little preference as to habitat, occurring in open fields, wooded areas and even in city lots. They appear to be primarily nocturnal, and their food consists chiefly of small rodents, although some small snakes and lizards are occasionally taken (J).

The eggs, which vary in number from 6 to 16, are thought to be laid primarily during June and July in the ground or refuse piles. The young, which are about 23 cm. long at hatching, appear in September and are usually redder than the adults (J).

(continued)

TABLE A-IV- 21. (continued)

Mud Turtle, *Kinosternon subrubrum subrubrum* x *hippocrepis*

The Mud Turtle is extremely rare in Illinois although habitats in southern Illinois are identical with habitats in the southern United States where it is common. The population that is present in Illinois is an intergrade population between the eastern and western subspecies (J).

Slender Glass Snake, *Ophisaurus attenuatus*

The Glass "Snake" is perhaps one of the most unusual of all the lizards in that it is completely without legs and has an extremely long tail that constitutes almost two-thirds of the total length of the animal. Adults will average about 60 cm. in length.

The Glass Snake is a rare lizard in Illinois. It was considered on the verge of extirpation 70 years ago. Apparently it is found most often in open or semi-open country, and in either dry or moist situations. The slender glass snake is terrestrial and somewhat fossorial, most often found on dissected hills. Insects, as well as small snails, slugs and spiders are consumed. The tail of this lizard is easily broken if the animal is injured or handled carelessly; hence the common name, Glass Snake (G,J).

Like most other species of lizards, the Glass Snake hibernates during the unfavorable winter months. An average of 12 eggs are laid during June or July, in most cases being brooded by the female, and hatched approximately two months later (J).

Scarlet Snake, *Cemophora coccinea copsi*

The only known specimen in Illinois was taken in Union County in 1942. None has been collected since, although it may occur on the slopes of Pine Hills, Union County. It is considered endangered in Illinois and may have already been extirpated from Illinois (G).

Western Mud Snake, *Farancia abacura reinwardti* (Schlegel)

This species is also called the Stinging Snake or the Hoop Snake. This species is a large (average length about one meter; record length: 12.54 meters) aquatic snake is one of the more attractively marked species found in Illinois. In this species, the male differs from the female in having a large, bulbar tail, conspicuous suranal zone of reduced scales, and keels on the suranal scales (L).

(continued)

TABLE A-IV-21. (continued)

This species inhabits shallow ponds, swamps, marshes, and sloughs with many partially decayed and water-soaked logs. It is a rather secretive species that spends much of its time buried in soft earth or rotted logs. The food consists primarily of amphibians, although some insects and worms are also eaten. The number of eggs laid by this snake varies from about 20 to as many as 100, although the average clutch would probably contain 30 to 35 eggs (J).

Mud Snake, *Farancia abacura*

This large (average length about 0.9 m, largest Illinois specimen 1.254 m) aquatic heavy-bodied snake is one of the more attractively marked species found in Illinois (I,J).

The Mud Snake, or Stinging Snake, Hoop Snake or Horn Snake as it is also sometimes called, is a rather secretive species that spends much of the time buried in soft earth or rotted logs. It occurs around muddy lakes and sloughs, swamps and marshes and is an uncommon to rare snake in Illinois. Its food consists primarily of amphibians, although some insects and worms are also eaten. The number of eggs laid by this snake varies from about 20 to as many as 100, although the average clutch would probably contain 30 to 35 eggs (I,J).

Amphibians

Hellbender, *Cryptobranchus alleganiensis alleganiensis*

The hellbender is a large aquatic salamander found in fast-running waters of rivers and large creeks. It is endangered in Illinois and is found in the southeastern portion of the State in the Ohio and Wabash Rivers including White County (G).

Eastern Wood Frog, *Rana sylvatica sylvatica*

This frog is extremely sporadic in occurrence, restricted to relatively mesic forests with permanent or semipermanent pools. It may be aquatic during the spring and fall, but during the summer it stays away from the water (G).

(continued)

TABLE A-IV-21. (continued)

Wood Frog, *Rana sylvatica*

In comparison to other frogs included in the family Ranidae, the Wood Frog is somewhat smaller and seldom reaches a length of over 5 cm. The Wood Frog is restricted to wooded sections and does not inhabit open areas. It is a relatively uncommon frog in Illinois (K). Breeding occurs in woodland pools rather early, usually during March and April. The eggs, varying in number from 2000 to 3000, are laid in masses and are normally attached to submerged vegetation of some type. The eggs hatch within one to three weeks, depending upon the temperature of the water. The development and eventual transformation of the tadpole requires six weeks to about three months. It is believed that, unlike most other members of the Ranidae, the Wood Frogs hibernate on land under logs, stones and other objects (K).

Birds

Black-crowned Night Heron, *Nycticorax nycticorax*

This species was a common summer resident, nesting colonially in trees or swampy areas among reeds. Now the Black-crowned night heron occurs statewide, but with spotty distribution. The population size is decreasing each year due to changes in its environment (G).

Hooded Merganser, *Lophodytes cucullatus*

Formerly the hooded merganser was a common summer resident on ponds and streams, nesting in hollow trees near water. It was also a common winter resident on Lake Michigan. Now it is rare as a nesting species in Illinois. Preferred habitats are swamps and flooded river areas. It is suspected to nest along the Ohio, Sangamon, Illinois, Mississippi, Wabash, and Rock Rivers (G).

Cooper's Hawk, *Accipiter cooperi*

This species was formerly common as a summer resident in Illinois. It is now endangered in Illinois. Cooper's hawk is most often found in the Shawnee Forest, but it is statewide in occurrence. Nesting occurs in the wooded hill country (G).

(continued)

TABLE A-IV-21. (continued)

Red-shouldered Hawk, *Buteo lineatus*

This hawk was formerly a common summer resident. It is now endangered in northern and central Illinois. In Illinois it occurs in bottomland forest and is found as a breeding species in the Shawnee Forest and southward (G).

Upland Sandpiper, *Bartramia longicauda*

Around 1900 the status of this species was given as moderately common, becoming less so every year. It is now endangered in Illinois. Its distribution is statewide, occurring in relatively short-grass prairies, sunny, dry uplands, and summer pastures (G).

Barn Owl, *Tyto alba*

The barn owl was formerly an uncommon permanent resident throughout the State, of casual occurrence in northern Illinois and breeding regularly in the southern part of the State. The population crashed in the early 1960's for unknown reasons. Now there are only scattered records mostly from southeast and northeast, and occasionally from northwest Illinois (G).

Saw-whet Owl, *Aegolius acadicus*

This species was formerly common in Illinois. There are no recent breeding records (G).

Bewick's Wren, *Thryomanes bewickii*

Formerly a common breeder in southern Illinois, Bewick's wren is now known to occur in Sand Ridge State Forest (Mason County) and southern Illinois as a rare resident (G).

Swainson's Warbler, *Limnothlypis swainsonii*

This warbler is a rare summer resident in southern Illinois. It is found in the southernmost eleven counties where there is canebrake, deciduous vegetation, or swampy areas next to creeks and rivers. One pair is known from as far north as southern Monroe County or western Randolph County along the Mississippi River (G).

(continued)

TABLE A-IV-21. (continued)

Pine Warbler, Dendroica pinus

Nesting populations of this species occur in pine trees in southern Illinois. There are no known northern nesting populations (G).

Cliff Swallow, Petrochelidon pyrrhonota

The range of this species in Illinois has been steadily receding to the north, leaving only relict populations in a few places. The decline in cliff swallows is probably due to competition by house sparrows for nesting sites (M).

Loggerhead Shrike, Lanius ludovicianus

Formerly a common summer resident in central Illinois and less common in the northern part of the State, the loggerhead shrike is now very scarce north of Springfield. It is more common in southern Illinois and can be found along highways. The disappearance of this species may be due to destruction of hedge rows and the disappearance of hay fields (G).

Loggerhead strikes are carnivorous. They eat diplopoda, insects, spiders and small vertebrates. An average of 93 (range 88-97) percent of their diet is insects (N). Since the shrikes are carnivorous, the possibility that their decline is due to the bioaccumulation of a toxic substance in their diet must be considered.

Southern Bald Eagle, Haliaeetus l. leucocephalus (O)

Arctic Peregrine Falcon,
Falco peregrinus tundrius (O)

Mammals

Gray Bat, Myotis grisescens

This bat is only known from Pike and Hardin Counties, but the presumed range is the entire southern half of Illinois. During the summer the gray bats congregate in limestone caverns. In the winter only a few remain to hibernate in Illinois caverns (G).

(continued)

Indiana Bat, Myotis sodalis

This bat is endangered in Illinois and throughout its range. The population size has decreased substantially in Illinois over the past few years. Its range includes the entire State; specimens have been taken from Hardin, LaSalle, Jo Daviess and Union Counties. Some of these bats may live in small colonies in caves during the summer. In the winter they hibernate in large compact clusters (G).

Southeastern Big-eared Bat, Corynorhinus rafinesquii

This bat possesses distinctive large ears. It is rare in the State of Illinois, the range extends southward from Illinois. Known only from Wabash, Union and Alexander Counties, the big-eared bat lives in caves during the winter and summer (G).

River Otter, Lutra canadensis

The river otter is sporadic in occurrence throughout most of Illinois. At one time it was fairly common along large Illinois streams. Streams and lakes provide suitable habitats for the river otter. The den is never far from water (G).

Bobcat, Lynx rufus

The bobcat is now endangered in Illinois, found only in certain regions of the southern and northwestern parts of the state. Wooded bottomlands and timbered bluffs along the major rivers bordering the state, and slopes interspersed with open areas are the preferred habitats (G).

References

**Reference A: Sheviak, C.J. Semifinal List of Endangered and Threatened Plants. January 18, 1978 Memo to Endangered Plants Workshop Participants from the Natural Land Institute, 819 North Main Street, Rockford, Illinois 61103, 1978.

Reference B: Paulson, G.A. and T. Schwegman. Endangered, Vulnerable, Rare and Extirpated Vascular Plants in Illinois. Interim List of Species. October 1976. Illinois Nature Preserves Commission, 819 N. Main Street, Rockford, Illinois 61103, 1976.

(continued)

TABLE A-IV-21. (continued)

Reference C: Johnson, T. Personal Communication, Southern Stream Project Biologist, State of Illinois, Department of Conservation, 1327 South Lincoln, Centralia, Illinois 62801, 1978.

Reference D: Krumholz, L.A., R.L. Bingham, and E.R. Meyer. A Survey of the Commercially Valuable Mussels of the Wabash and White Rivers of Indiana. Proceedings of the Indiana Academy of Science for 1969, 79:205-226, 1970.

Reference E: Parmalee, P.W. The Fresh-Water Mussels of Illinois, Popular Science Series, Vol. VIII, Printed by Authority of the State of Illinois, Springfield, Illinois, 1967.

Reference F: State of Illinois. Rare and Endangered Fish of Illinois. Department of Conservation, Division of Fisheries, Springfield, Illinois 62706, 1973.

Reference G: Ackerman, K. Rare and Endangered Vetebrates of Illinois. Illinois Department of Transportation, 2300 South Dirksen Parkway, Springfield, Illinois, 1975 (with 1977 Modification).

Reference H: Smith, P.W. A Preliminary Annotated List of the Lampreys and Fishes of Illinois. Illinois Natural History Survey, Biological Notes No. 54, Urbana, Illinois, State of Illinois, Department of Registration and Education, Natural History Survey Division, 1965.

Reference I: Smith, P.W. Illinois Streams: A Classification Based on Their Fishes and an Analysis of Factors Responsible for Disappearance of Native Species. Biological Notes No. 76, Illinois Natural History Survey, Urbana, Illinois. State of Illinois, Department of Registration and Education, Natural History Survey Division, 1971.

Reference J: Parmalee, P.W. Reptiles of Illinois, Popular Science Series, Volume V, Printed by Authority of the State of Illinois, Springfield, Illinois, 1955.

Reference K: Parmalee, P.W. Amphibians of Illinois. Story of Illinois Series, No. 10. Printed by Authority of the State of Illinois, Illinois State Museum, Springfield, Illinois, 1954.

(continued)

TABLE A-IV-21. (continued)

Reference L: Smith, P.W. The Amphibians and Reptiles of Illinois. Illinois Natural History Survey Bulletin 28(1). State of Illinois, Department of Registration and Education, Natural History Survey Division, Urbana, Illinois, 1961 (Reprinted 1971).

Reference M: Graber, R.R., J.W. Graber and E.L. Kirk. Illinois Birds: Hirundinidae. Biological Notes No. 80. Illinois Natural History Survey, Urbana, Illinois, 1972.

Reference N: Graber, R.R., J.W. Graber, and E.L. Kirk. Illinois Birds: Laiidae. Biological Notes No. 83, Illinois History Survey, Urbana, Illinois, 1973.

Reference O: Beck, R.W. and Associates. Environmental Analysis Merom Generating Station for Hoosier Energy Division of Indiana Statewide R.E.C., Inc. 1976.

APPENDIX V

ENVIRONMENTAL EFFECTS INFORMATION, WHITE COUNTY, ILLINOIS

A-V ENVIRONMENTAL EFFECTS INFORMATION, WHITE COUNTY, ILLINOIS

A-V-1 Site Factors Affecting Environmental Distribution and/or Acting to Dissipate/Exacerbate Ecotoxicological Effects of Pollutant

A-V-1.1 Abiotic Site-Specific Factors

A-V.1.1.1 Atmospheric Factors (1,2,3)

Table A-V-1 is the 1976 annual summary of climatological data for Evansville, Indiana. Evansville is the closest first-order weather station to White County and the data contained in this table on winds and precipitation are the best available which are applicable to White County, Illinois.

The accuracy of any prediction as to the possible atmospheric pollution in the region of White County can be improved by use of the computerized "Climatological Analysis of Pasquill Stability Categories Based on 'STAR' Summaries." These computer analyses are prepared by the National Oceanic and Atmospheric Administration, National Climatic Center, Federal Building, Asheville, NC 28801. The computer program, called "STAR" (STability ARray), utilizes the meterological variables, wind and cloudiness. The STAR program has been widely applied throughout the United States in making diffusion calculations.

The STAR program has been found to give a good first approximation of the stability (instability) of the atmosphere where no low-level temperature and wind profile data exist. Stability near the ground is dependent primarily upon net radiation and wind speed. Wind direction is not a factor in the objective determination of stability categories.

TABLE A-V-1. LOCAL CLIMATOLOGICAL DATA ANNUAL SUMMARY FOR EVANSVILLE, INDIANA IN 1976 (1)

Meteorological Data For The Current Year

Station EVANSVILLE, INDIANA # 93817 DRESS REGIONAL AIRPORT Standard time used CENTRAL Latitude 38° 03' N Longitude 87° 32' W Elevation (ground) 381 feet Year 1976

Month	Temperature °F							Degree days Base 65 °F		Precipitation in inches						Relative humidity pct				Wind						Percent of possible sunshine	Average sky cover, tenths, sunrise to sunset	Number of days											Average station pressure mb
	Averages			Extremes						Water equivalent			Snow, Ice pellets			Hour 00	Hour 06	Hour 12	Hour 18	Resultant		Average speed m.p.h.	Fastest mile					Sunrise to sunset			Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog, visibility 1/4 mile or less	Temperature °F				Elev. 389 feet m.s.l.
																(Local time)																			Maximum		Minimum		
	Daily maximum	Daily minimum	Monthly	Highest	Date	Lowest	Date	Heating	Cooling	Total	Greatest in 24 hrs.	Date	Total	Greatest in 24 hrs.	Date					Direction	Speed m.p.h.		Speed m.p.h.	Direction	Date			Clear	Partly cloudy	Cloudy					(b) 90° and above	32° and below	32° and below	0° and below	
JAN	37.8	20.8	29.3	60	13	-1	9	1100	0	2.11	1.14	25	2.9	1.8	7-8	80	82	69	70	27	2.8	9.0	46	W	13	54	6.4	8	8	15	8	1	1	1	0	9	29	2	1007.1
FEB	54.0	32.2	43.1	73	29	8	3	628	0	2.61	1.89	17	0.8	0.6	2	78	82	62	64	22	5.0	10.8	35	SW	19	63	7.1	5	5	19	6	0	3	0	0	4	14	0	1003.6
MAR	63.1	40.0	51.6	79	4	23	17	417	6	2.29	0.66	20	0.2	0.2	16	80	84	61	59	21	4.8	10.9	36	SW	27	76	6.2	5	15	11	10	0	4	0	0	0	8	0	1002.0
APR	70.8	43.5	57.2	88	20	31	13	273	47	1.30	0.92	24-25	0.0	0.0		74	83	49	51	22	1.8	8.9	29	SW	21	81	5.0	12	7	11	9	0	3	0	0	0	4	0	1004.6
MAY	72.7	50.5	61.6	84	21	32	4	139	40	7.48	2.14	13-14	0.0	0.0		73	75	55	55	19	0.1	8.0	42	SW	15	67	5.9	12	2	17	11	0	4	0	0	0	1	0	[illegible]
JUN	83.4	63.2	73.3	93	14	54	6	0	258	4.24	1.92	24-25	0.0	0.0		79	74	54	53	22	1.4	6.9	28	S	15	66	5.4	10	10	10	11	0	3	0	6	0	0	0	1002.3
JUL	88.0	66.0	77.0	100	24	56	18	0	379	2.14	1.01	28-29	0.0	0.0		83	85	54	56	27	2.3	5.4	18	SW	15	78	4.8	11	15	5	4	0	6	0	13	0	0	0	1002.7
AUG	85.6	61.6	73.6	92	27	51	30	0	274	0.24	0.12	14-15	0.0	0.0		81	85	50	54	05	1.1	5.9	16	NW	14	75	4.6	12	10	9	5	0	2	0	6	0	0	0	1005.4
SEP	79.9	54.3	67.1	88	8	39	22	27	98	3.29	1.72	1	0.0	0.0		78	82	50	60	35	0.7	5.1	18	NW	21	68	4.5	13	9	8	6	0	2	3	0	0	0	0	1003.9
OCT	64.3	40.5	52.4	84	4	24	29	391	10	4.82	3.00	23-24	0.0	0.0		67	73	48	55	34	1.1	6.4	24	S	30	56	5.2	14	4	13	7	0	0	1	0	0	6	0	1005.1
NOV	49.1	28.2	38.7	66	18	10	30	788	0	1.09	1.00	26	0.3	0.3	27-28	60	63	47	52	28	4.2	7.5	26	S	29	64	4.5	12	10	8	2	0	0	0	0	3	23	0	1004.9
DEC	42.4	21.2	31.8	67	19	-3	31	1021	0	0.56	0.19	28-29	4.3	4.2	28-29	70	70	57	63	27	3.1	8.2	28	NW	20	65	5.3	13	6	12	8	1	0	2	0	5	29	2	1009.1
YEAR	65.9	43.5	54.7	100	JUL 24	-3	DEC 31	4784	1112	32.09	3.00	OCT 23-24	8.5	4.2	DEC 28-29	75	78	55	58	25	1.8	7.6	46	W	JAN 13	69	5.4	127	101	138	87	2	26	7	25	21	114	4	1004.1

Normals, Means, And Extremes

Month	Temperatures °F							Normal Degree days Base 65 °F		Precipitation in inches											Relative humidity pct				Wind					Pct. of possible sunshine	Mean sky cover, tenths, sunrise to sunset	Mean number of days											Average station pressure mb
	Normal			Extremes						Water equivalent							Snow, Ice pellets				Hour 00	Hour 06	Hour 12	Hour 18			Fastest mile					Sunrise to sunset			Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog, visibility 1/4 mile or less	Temperatures °F				Elev. 388 feet m.s.l.
																					(Local time)																		Max.		Min.		
	Daily maximum	Daily minimum	Monthly	Record highest	Year	Record lowest	Year	Heating	Cooling	Normal	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs.	Year	Maximum monthly	Year	Maximum in 24 hrs.	Year					Mean speed m.p.h.	Prevailing direction	Speed m.p.h.	Direction	Year			Clear	Partly cloudy	Cloudy					(b) 90° and above	32° and below	32° and below	0° and below	
(a)				36		36					36		36		36		36		36		15	15	15	15	36	14	36	36		36	36	36	36	36	36	36	36	36	15	15	15	15	-
J	41.5	23.7	32.6	76	1943	-18	1963	1004	0	3.40	13.50	1950	0.59	1943	3.23	1959	12.3	1951	8.2	1951	75	76	67	63	9.5	SSW	47	W	1971	42	7.1	7	6	18	11	3	1	2	0	10	25	2	[illegible]
F	45.4	26.4	35.9	79	1962	-23	1951	815	0	3.27	7.25	1956	0.27	1947	3.13	1965	11.3	1948	8.7	1966	74	77	64	63	9.9	NW	59	W	1956	48	6.7	7	6	15	9	1	1	1	0	4	21	1	[illegible]
M	54.6	34.0	44.3	83	1945	-9	1960	653	11	4.69	12.84	1964	0.89	1941	5.03	1964	20.2	1960	10.6	1960	75	80	62	61	10.4	WNW	56	S	1945	55	6.7	6	8	17	12	1	4	1	0	1	14	0	[illegible]
A	67.9	45.5	56.7	90	1967	24	1972	282	14	4.06	7.99	1955	1.10	1959	3.95	1955	8.6	1971	8.6	1971	73	77	55	55	10.0	SSW	54	NW	1958	60	6.5	7	8	15	11	*	5	*	*	0	2	0	1002.5
M	77.0	54.4	65.7	95	1975	28	1963	95	117	4.38	12.22	1961	0.91	1965	6.05	1961	0.0		0.0		79	81	55	56	8.2	SSW	55	NW	1957	66	6.2	8	9	14	11	0	6	1	2	0	*	0	999.8
J	86.0	63.4	74.7	104	1954	41	1966	5	296	3.57	9.30	1943	1.15	1953	3.26	1971	0.0		0.0		80	81	55	57	7.3	SW	58	NW	1958	73	5.7	8	11	11	10	0	8	1	8	0	0	0	[illegible]
J	88.9	66.7	77.8	105	1954	47	1947	0	387	3.77	9.69	1958	0.18	1974	3.67	1967	0.0		0.0		83	84	56	58	6.3	SW	53	NW	1961	76	5.5	9	12	10	10	0	8	1	14	0	0	0	1004.3
A	88.0	64.4	76.2	102	1964	46	1966	0	347	2.95	7.18	1959	0.13	1963	2.64	1973	0.0		0.0		85	87	58	61	5.9	SW	49	NW	1963	76	5.1	11	11	9	7	0	5	1	10	0	0	0	1004.2
S	81.4	56.7	69.1	103	1954	31	1942	36	197	2.80	9.89	1945	0.56	1953	3.45	1965	0.0		0.0		86	88	58	67	6.6	SSW	49	SW	1961	70	5.1	11	9	10	7	0	3	1	3	0	0	0	[illegible]
O	71.2	45.2	58.2	94	1953	21	1952	236	23	2.52	8.33	1941	0.01	1964	3.00	1976	T	1957	T	1957	79	82	52	63	7.0	NW	37	S	1946	67	4.8	14	7	10	7	0	2	2	*	0	4	0	1006.2
N	55.2	34.5	44.9	83	1961	-3	1950	603	0	3.17	8.49	1957	0.91	1965	2.68	1957	6.9	1958	6.9	1958	75	78	61	67	8.8	NW	47	SW	1940	49	6.3	8	7	15	9	*	1	1	0	1	13	0	1005.4
D	44.0	26.5	35.3	73	1951	-9	1963	921	0	3.30	7.95	1951	0.56	1976	2.07	1972	10.4	1973	7.0	1963	77	79	68	72	9.0	NW	50	SW	1971	41	7.0	7	6	18	11	1	1	2	0	6	23	1	1005.2
YR	66.8	45.1	56.0	105	JUL 1954	-23	FEB 1951	4629	1364	41.88	13.50	JAN 1950	0.01	OCT 1964	6.05	MAY 1961	20.2	MAR 1960	10.6	MAR 1960	78	81	59	62	8.3	SSW	59	W	FEB 1956	67	6.1	103	100	162	114	6	45	16	39	21	103	3	1003.5

Means and extremes above are from existing and comparable exposures. Annual extremes have been exceeded at other sites in the locality as follows: Highest temperature 108 in July 1936; maximum monthly precipitation 14.78 in January 1937; maximum precipitation in 24 hours 6.94 in October 1910; maximum monthly snowfall 41.0 in January 1918; maximum snowfall in 24 hours 20.8 in January 1918; fastest mile of wind 113 from South in June 1919.

(a) Length of record, years, through the current year unless otherwise noted, based on January data.
(b) 70° and above at Alaskan stations.
* Less than one half
T Trace.

NORMALS - Based on record for the 1941-1970 period.
DATE OF AN EXTREME - The most recent in cases of multiple occurrence.
PREVAILING WIND DIRECTION - Record through 1963.
WIND DIRECTION - Numerals indicate tens of degrees clockwise from true north. 00 indicates calm.
FASTEST MILE WIND - Speed is fastest observed 1-minute value when the direction is in tens of degrees.

(continued)

TABLE A-V-1. (continued)

Average Temperature

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1937	38.1	35.8	42.7	56.0	67.6	76.6	78.1	81.0	69.6	56.8	44.2	34.6	56.8
1938	34.8	45.6	53.6	55.5	67.6	73.6	79.1	79.8	72.6	63.8	48.1	37.8	59.7
1939	41.0	37.1	49.2	53.8	68.8	76.6	78.6	77.7	77.1	62.6	45.3	38.8	59.0
*1940	19.5	35.3	44.2	54.5	63.3	76.0	78.2	79.5	67.0	61.0	43.9	40.8	55.4
1941	35.2	31.8	40.0	59.3	67.6	75.6	78.6	77.6	72.6	62.6	48.1	40.0	57.1
1942	30.6	33.6	46.8	57.7	66.8	74.6	78.5	75.3	67.8	57.6	48.6	32.9	55.7
1943	33.8	37.9	40.2	53.6	66.5	77.2	78.8	79.2	65.3	56.2	42.8	32.6	55.3
1944	36.3	39.2	42.9	54.8	69.6	78.0	77.8	77.0	69.2	57.6	46.5	30.1	56.6
1945	29.8	30.0	54.5	57.2	60.8	71.0	74.6	74.6	70.1	56.2	46.2	29.0	55.0
1946	36.0	39.2	56.3	59.0	62.0	74.2	76.5	71.1	67.6	59.6	48.2	40.8	57.6
1947	38.1	27.8	37.0	56.0	62.0	72.1	72.8	81.1	69.6	64.6	41.8	36.8	55.0
1948	25.6	35.0	46.9	58.2	63.8	74.6	77.6	75.0	69.9	54.8	47.6	40.0	55.7
1949	39.0	38.5	45.0	53.7	66.6	75.6	80.0	76.0	63.6	61.0	48.2	40.3	57.1
1950	42.5	38.6	42.1	51.1	66.9	73.1	74.3	72.0	67.2	62.6	40.1	29.2	55.0
*1951	33.5	35.7	42.2	52.7	66.2	74.0	78.0	76.6	66.8	59.2	39.0	37.2	55.1
1952	38.2	40.7	46.5	55.1	65.7	81.1	79.8	76.5	67.9	52.0	46.0	38.5	57.2
1953	37.9	40.6	47.8	52.7	67.8	80.2	79.9	77.1	70.2	59.6	45.7	35.9	57.9
1954	34.2	44.5	43.7	61.5	60.8	77.7	81.1	78.6	73.0	58.8	45.9	36.9	58.0
1955	33.2	37.2	45.9	60.9	67.0	69.3	81.8	78.8	72.6	57.3	42.5	33.5	56.7
1956	31.2	40.5	46.9	53.6	66.9	74.8	77.7	78.6	67.2	61.8	44.1	42.6	56.8
1957	29.8	41.5	46.7	59.3	65.9	75.5	77.8	75.9	68.8	54.1	44.3	41.2	56.6
1958	32.0	26.6	39.5	55.2	65.3	71.6	77.5	76.2	69.3	57.3	47.6	29.3	53.9
1959	30.9	37.6	46.7	56.8	69.0	74.6	76.8	78.7	70.9	57.5	40.1	39.6	56.6
1960	36.5	32.7	30.2	58.5	62.6	73.6	75.7	77.7	72.9	58.9	45.1	30.6	54.5
*1961	29.6	39.6	49.6	52.7	61.6	72.0	77.2	75.1	72.3	58.8	45.7	34.3	55.7
1962	28.3	39.6	43.2	55.8	70.6	74.6	77.7	76.6	69.5	59.2	44.3	30.0	55.7
1963	23.9	28.7	49.6	57.7	63.5	74.5	76.7	74.7	67.6	64.0	47.1	24.2	54.3
1964	34.7	33.8	45.6	59.8	67.7	75.6	77.6	75.6	68.4	52.9	47.5	36.3	56.3
1965	32.3	33.9	38.8	57.5	69.7	73.7	76.2	74.6	69.7	55.9	48.1	41.5	55.8
1966	26.6	32.8	46.6	53.3	61.2	73.6	81.8	74.6	65.5	54.1	46.6	35.0	54.3
1967	36.9	31.7	49.2	59.6	61.6	73.6	73.6	70.1	66.1	57.3	42.0	37.6	54.9
1968	28.5	30.6	45.7	56.6	63.2	74.5	77.7	77.6	68.6	56.9	45.9	34.3	54.9
1969	31.5	36.5	38.3	56.1	65.0	74.4	79.2	74.6	68.3	56.7	41.6	31.5	54.5
1970	24.0	32.6	41.6	58.7	68.4	72.0	75.3	75.6	73.5	57.1	44.6	37.5	55.0
1971	29.8	33.6	42.0	56.1	63.4	79.3	77.1	76.6	72.7	63.8	45.7	42.1	56.9
1972	32.5	34.1	44.2	56.4	66.0	71.4	75.6	73.8	70.9	53.4	41.5	34.6	54.5
1973	32.7	34.6	53.6	55.1	62.4	75.8	79.1	77.5	73.2	62.1	49.6	34.1	57.5
1974	37.4	40.0	50.1	57.0	67.0	70.9	79.4	74.2	63.2	56.7	47.4	36.9	56.6
1975	36.8	38.3	42.6	55.1	69.6	76.2	77.8	77.3	66.5	58.4	48.8	36.9	57.0
1976	29.3	43.1	51.6	57.2	61.6	73.3	77.0	73.6	67.1	52.4	38.7	31.8	54.7
RECORD													
MEAN	33.7	38.0	45.7	56.3	66.0	75.1	78.7	77.0	70.5	59.1	46.1	36.2	56.7
MAX	41.7	46.4	54.9	66.2	76.1	85.3	88.7	87.2	81.5	70.2	55.2	43.8	66.2
MIN	25.7	27.6	36.4	46.3	55.8	64.9	68.6	66.8	59.7	48.0	37.0	28.5	47.1

Heating Degree Days

EVANSVILLE, IN

Season	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	Total
1956-57	0	4	35	121	623	688	1083	650	623	258	92	2	4181
1957-58	0	0	28	333	618	727	1016	1074	703	281	77	8	4968
1958-59	0	3	39	256	529	1103	1048	768	624	264	58	0	4692
1959-60	0	6	22	272	761	780	874	932	1074	288	164	8	5180
1960-61	0	0	6	215	601	1060	1097	706	472	386	169	11	4691
*1961-62	0	1	44	209	582	948	1131	706	667	323	3	0	4615
1962-63	0	0	92	223	613	1075	1269	1008	471	230	112	0	5119
1963-64	0	0	44	86	532	1238	937	898	601	193	48	8	4603
1964-65	0	8	52	367	518	883	1008	867	867	254	18	0	4844
1965-66	0	5	30	287	500	727	1192	894	566	330	169	15	4721
1966-67	0	0	57	341	584	923	864	928	498	218	161	11	4538
1967-68	1	11	72	264	684	866	1128	997	593	286	111	3	4968
1968-69	0	0	13	262	589	966	1029	783	819	269	90	13	4823
1969-70	0	0	35	289	693	1034	1266	896	716	223	57	1	5282
1970-71	2	0	26	235	603	846	1087	874	707	290	90	0	4780
1971-72	0	0	23	85	571	701	1000	887	639	274	64	18	4260
1972-73	2	3	26	350	702	940	997	844	343	312	106	0	4633
1973-74	0	0	11	160	459	934	849	806	480	289	71	8	3950
1974-75	0	0	124	280	537	863	867	742	689	319	23	0	4446
1975-76	0	0	78	223	484	861	1100	628	417	273	139	0	4202
1976-77	0	0	27	391	786	1021							

Cooling Degree Days

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
1969	0	0	0	8	83	300	448	307	148	48	0	0	1326
1970	0	0	0	43	169	220	329	331	286	18	0	0	1396
1971	0	0	0	28	49	437	382	367	262	53	0	0	1576
1972	0	0	1	21	99	214	337	283	196	2	4	0	1160
1973	0	0	0	23	35	331	438	396	263	78	3	0	1567
1974	0	0	26	28	141	188	452	292	73	14	15	0	1229
1975	0	0	0	29	176	342	406	386	129	29	1	0	1500
1976	0	0	8	47	40	238	378	274	98	10	0	0	1112

Precipitation

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1937	14.78	1.88	0.62	4.24	5.02	3.09	1.76	3.45	1.80	5.57	1.57	2.71	49.09
1938	3.54	2.71	4.69	0.81	3.95	3.14	5.28	4.11	1.81	0.35	2.33	1.54	36.28
1939	5.32	6.66	4.34	6.05	2.55	3.31	5.96	3.65	0.30	1.91	1.79	1.81	43.82
*1940	2.36	3.91	1.75	6.37	2.49	2.70	2.07	1.66	0.91	1.47	4.76	2.32	32.77
1941	2.28	0.70	0.89	2.21	2.13	3.53	4.30	3.85	0.71	8.33	2.22	2.44	33.59
1942	2.68	3.00	5.06	3.91	5.19	3.23	1.54	2.09	1.63	1.45	6.07	2.80	39.25
1943	0.59	0.99	9.40	3.61	6.30	9.30	2.88	0.13	3.91	1.48	1.70	1.86	42.01
1944	0.74	3.13	4.63	6.35	2.95	1.61	0.99	2.45	2.14	0.27	1.67	3.96	30.89
1945	1.89	6.33	11.43	5.23	2.80	6.85	3.74	5.39	9.89	1.94	4.32	2.16	61.95
1946	2.69	5.37	1.59	2.16	7.39	3.06	3.06	5.55	1.65	1.77	4.47	3.00	41.90
1947	3.83	0.27	2.38	5.48	3.77	5.26	3.65	2.26	3.39	2.73	2.18	2.50	37.90
1948	2.02	3.27	3.77	3.98	4.19	1.85	5.10	1.63	4.33	2.35	6.14	3.01	42.24
1949	8.84	3.31	8.50	2.73	3.54	4.81	3.19	3.80	2.36	7.01	0.97	4.28	53.54
1950	13.50	6.60	4.67	5.91	5.54	3.92	7.18	5.22	2.79	1.05	5.07	1.68	63.13
*1951	6.75	4.64	6.21	3.51	1.74	4.76	2.83	1.81	3.42	2.02	5.73	7.95	51.37
1952	3.31	4.41	8.63	3.00	3.61	3.29	1.82	3.01	2.07	1.07	2.04	3.09	37.35
1953	3.93	1.61	4.63	5.50	4.22	1.15	2.50	1.22	0.56	1.42	1.36	1.93	29.03
1954	4.90	2.05	1.90	3.71	3.45	1.35	2.16	4.22	3.38	2.16	0.99	3.92	33.83
1955	1.03	5.17	4.38	7.99	3.32	3.06	2.99	1.31	2.88	3.78	3.91	0.72	40.52
1956	2.22	7.25	2.68	3.23	3.38	2.60	2.23	2.98	1.62	1.06	2.32	2.76	34.31
1957	4.18	3.37	1.93	6.32	8.22	4.95	2.75	2.12	1.43	3.51	8.49	6.41	53.08
1958	3.00	1.36	3.63	4.52	3.84	5.03	9.69	1.77	3.50	1.70	3.17	1.23	42.22
1959	3.31	2.80	2.34	1.10	7.80	3.24	5.44	7.18	1.88	2.80	1.34	3.89	43.12
1960	1.89	2.58	2.87	2.75	3.97	6.36	1.83	2.31	1.43	2.29	3.60	2.00	34.48
1961	0.97	3.56	4.81	4.42	12.22	2.96	2.73	5.23	0.84	0.55	4.82	4.29	[illegible]
1962	4.38	6.38	4.69	1.26	5.39	2.73	1.81	2.11	5.11	2.75	1.36	2.76	[illegible]
1963	0.85	0.82	8.62	1.13	3.62	1.23	5.20	2.47	1.00	0.42	1.33	[illegible]	27.88
1964	2.19	1.57	12.86	6.85	1.88	1.58	2.35	1.17	3.50	0.01	2.34	[illegible]	38.37
1965	2.53	5.01	2.99	2.97	0.91	2.03	6.09	3.83	5.18	1.07	0.91	1.31	35.03
1966	2.89	4.67	1.34	5.33	3.48	1.74	1.96	2.26	3.33	1.65	2.38	5.52	36.53
1967	1.09	2.13	3.54	3.03	3.81	1.60	5.44	3.15	1.19	7.92	3.88	5.31	43.19
1968	2.44	1.76	4.70	3.59	4.13	3.07	5.59	2.58	3.09	2.10	4.60	5.60	43.21
1969	7.98	1.39	2.08	3.51	5.36	4.98	8.72	1.91	2.08	4.20	3.29	3.19	49.23
1970	1.00	2.37	6.30	7.74	3.33	5.94	3.49	2.82	3.25	4.70	1.98	2.01	45.93
1971	2.88	4.90	1.65	2.81	3.96	0.89	3.38	2.17	4.47	2.42	1.37	3.15	40.25
1972	1.68	3.05	5.05	6.66	1.84	1.92	5.31	2.47	1.25	3.06	5.47	4.49	42.27
1973	2.65	1.65	6.97	5.47	5.57	5.24	3.41	2.83	0.73	1.99	6.02	3.85	46.18
1974	3.68	1.51	4.56	3.66	6.38	3.81	0.18	6.89	3.90	1.88	3.85	3.06	43.27
1975	4.05	4.08	7.18	6.62	3.63	3.07	3.13	3.47	2.60	2.73	4.21	4.26	51.01
1976	2.11	2.01	2.29	1.30	7.48	4.24	2.14	0.24	3.29	4.82	1.08	0.36	32.09
RECORD													
MEAN	3.65	3.17	4.28	3.94	4.08	3.87	3.41	3.17	3.18	2.72	3.42	3.36	42.17

Snowfall

Season	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	Total
1937-38	0.0	0.0	0.0	0.0	2.0	0.9	6.7	0.1	T	T	0.0	0.0	9.7
1938-39	0.0	0.0	0.0	0.0	0.5	0.9	3.3	13.4	T	T	0.0	0.0	18.3
1939-40	0.0	0.0	0.0	T	T	11.2	13.6	1.6	0.1	T	0.0	0.0	26.7
*1940-41	0.0	0.0	0.0	0.0	T	0.0	0.3	1.5	T	0.0	0.0	0.0	1.8
1941-42	0.0	0.0	0.0	0.0	T	0.6	5.1	3.9	T	0.0	0.0	0.0	9.6
1942-43	0.0	0.0	0.0	T	0.0	4.5	0.2	1.0	2.9	T	0.0	0.0	10.6
1943-44	0.0	0.0	0.0	0.0	T	1.5	0.6	3.0	0.4	0.0	0.0	0.0	5.5
1944-45	0.0	0.0	0.0	0.0	T	3.0	6.9	1.5	T	T	0.0	0.0	11.4
1945-46	0.0	0.0	0.0	0.0	T	6.5	1.2	2.9	0.0	0.0	0.0	0.0	10.6
1946-47	0.0	0.0	0.0	0.0	T	1.6	0.3	3.7	10.9	0.0	0.0	0.0	16.5
1947-48	0.0	0.0	0.0	0.0	T	0.9	4.6	11.3	0.6	0.0	0.0	0.0	17.4
1948-49	0.0	0.0	0.0	0.0	0.4	0.7	2.7	T	5.8	T	0.0	0.0	9.6
1949-50	0.0	0.0	0.0	0.0	T	0.3	2.1	T	T	T	0.0	0.0	2.4
*1950-51	0.0	0.0	0.0	0.0	2.6	3.5	12.3	3.3	4.2	T	0.0	0.0	26.1
1951-52	0.0	0.0	0.0	T	2.1	2.0	0.5	4.4	1.1	T	0.0	0.0	10.1
1952-53	0.0	0.0	0.0	T	1.3	4.5	3.5	T	1.2	1.8	0.0	0.0	12.3
1953-54	0.0	0.0	0.0	0.0	T	1.2	5.0	T	T	0.0	0.0	0.0	6.2
1954-55	0.0	0.0	0.0	T	T	3.3	5.5	0.1	0.4	0.0	0.0	0.0	9.3
1955-56	0.0	0.0	0.0	T	T	0.5	7.8	T	T	0.0	0.0	0.0	8.3
1956-57	0.0	0.0	0.0	0.0	0.8	T	1.8	T	T	T	0.0	0.0	2.6
1957-58	0.0	0.0	0.0	T	T	0.6	2.6	0.7	5.1	0.0	0.0	0.0	9.0
1958-59	0.0	0.0	0.0	0.0	6.9	1.0	1.9	T	T	0.0	0.0	0.0	9.8
1959-60	0.0	0.0	0.0	0.0	T	T	0.5	9.3	20.2	T	0.0	0.0	30.0
1960-61	0.0	0.0	0.0	0.0	T	6.4	4.4	8.2	T	1.3	0.0	0.0	20.3
1961-62	0.0	0.0	0.0	0.0	0.2	3.2	2.9	2.0	0.2	0.1	0.0	0.0	10.9
1962-63	0.0	0.0	0.0	0.0	T	0.9	3.2	0.8	T	0.0	0.0	0.0	4.9
1963-64	0.0	0.0	0.0	0.0	T	8.2	4.8	3.2	T	0.0	0.0	0.0	16.2
1964-65	0.0	0.0	0.0	0.0	1.2	T	4.5	9.7	2.6	0.0	0.0	0.0	18.0
1965-66	0.0	0.0	0.0	0.0	T	T	2.9	10.2	0.8	T	0.0	0.0	13.9
1966-67	0.0	0.0	0.0	0.0	2.8	0.6	0.1	5.1	7.2	0.0	0.0	0.0	15.8
1967-68	0.0	0.0	0.0	0.0	T	0.9	10.0	0.7	6.7	0.0	0.0	0.0	18.3
1968-69	0.0	0.0	0.0	0.0	0.3	T	4.3	7.0	0.8	0.0	0.0	0.0	12.6
1969-70	0.0	0.0	0.0	0.0	2.0	7.7	3.4	7.4	13.2	T	0.0	0.0	37.7
1970-71	0.0	0.0	0.0	0.0	T	0.5	0.6	8.5	4.2	8.6	0.0	0.0	22.5
1971-72	0.0	0.0	0.0	0.0	3.4	T	2.0	1.5	0.1	T	0.0	0.0	7.0
1972-73	0.0	0.0	0.0	0.0	0.3	3.5	0.6	1.6	T	0.3	0.0	0.0	6.3
1973-74	0.0	0.0	0.0	0.0	0.8	10.4	0.4	1.0	3.4	T	0.0	0.0	16.2
1974-75	0.0	0.0	0.0	0.0	T	3.0	1.3	1.3	13.2	T	0.0	0.0	19.1
1975-76	0.0	0.0	0.0	0.0	1.7	1.3	2.9	0.8	0.2	0.0	0.0	0.0	6.9
1976-77	0.0	0.0	0.0	0.0	0.3	4.3							
RECORD													
MEAN	0.0	0.0	0.0	T	0.7	2.5	3.2	3.2	3.0	0.3	0.0	0.0	12.9

* Indicates a station move or relocation of instruments. See Station Location table.

Record mean values above are means through the current year for the period beginning in 1897 for temperature, 1878 for precipitation and 1941 for snowfall. Data are from City Office locations through July 1940.

Without the influence of clouds, insolation (incoming radiation) during the day is dependent upon the solar elevation, which is a function of time of day, time of year and station location. When clouds exist, their cover and thickness decrease incoming and outgoing radiation. In this system, insolation is estimated by solar elevation and modified for existing conditions of total cloud cover and cloud ceiling height. At night, estimates of outgoing radiation are again based on total cloud cover and ceiling height.

The STAR classification of stability is broken down into categories A through F, which are described along with typical plume behavior in Table A-V-2. Figure A-V-1 graphically illustrates plumes under these various stability categories.

Atmospheric stability conditions for the Evansville, Indiana area were tabulated by the National Climatic Center. Since Evansville is the closest reporting station to White County for which stability data are available, this station must be used to determine the air stability of White County. The stability conditions at Dress Regional Airport in Evansville, on both an annual and seasonal basis, are as shown in Table A-V-3.

Stability Classes E and F were combined into a single Class E in the above table of Evansville stability because urban areas do not become as stable in the lower layers as nonurban areas such as White County.

The joint probability distribution of stability and various wind speed ranges (11.0 meters per second is 24.6 miles per hour) for Evansville on an annual basis, are as shown in Table A-V-4.

TABLE A-V-2. STABILITY CATEGORIES

Stability Class	Description	Plume Behavior
A - Extremely Unstable	This classification is associated with conditions of low surface wind speeds and strong solar radiation.	There are rapid changes in wind direction with time. Surface heating has eliminated all temperature inversions near the ground. Wind speeds are generally less than 18 km per hour. Rapidly rising parcels of warm air from near the earth's surface are replaced by equal amounts of air moving downward nearby. A plume is carried with this "looping" motion. It is typical that cumulus clouds will be seen above terrain. Highly transitory maxima in ground-level concentration relatively near the source occur with this category.
B - Moderately Unstable	This stability class is most common when the wind speeds are slightly higher (6 to 10 km per hour) and the solar radiation is still strong.	
C - Slightly Unstable	This category is typified by wind speeds from 11 to 16 km per hour with moderate to strong radiation or lower wind speeds coupled with slight radiation.	
D - Neutral	Conditions which produce this type of stability are fairly high wind speeds during a period of slight solar radiation or at night.	This category includes most cases with winds stronger than 19 km per hour. Duration is 2 hours or more. The vertical temperature profile is near the adiabatic lapse rate. A plume is dispersed rapidly with a "coning" motion.
E - Slightly Stable	This classification is associated with wind speeds from 6 to 10 km per hour at night.	Coolest air is located at the earth's surface and stack plumes more horizontally at effective stack height. Almost no pollution can be measured at the ground.

(continued)

TABLE A-V-2. (continued)

Stability Class	Description	Plume Behavior
F - Moderately Stable	This level of stability is found at night when wind speed is even lower than in Class E.	
Transition	Conditions which change in a relatively short period of time from stable to neutral or unstable.	A portion of the plume will experience limited mixing prior to complete linkage of surface airflow to synoptic airflow, which is controlled by pressure pattern winds.

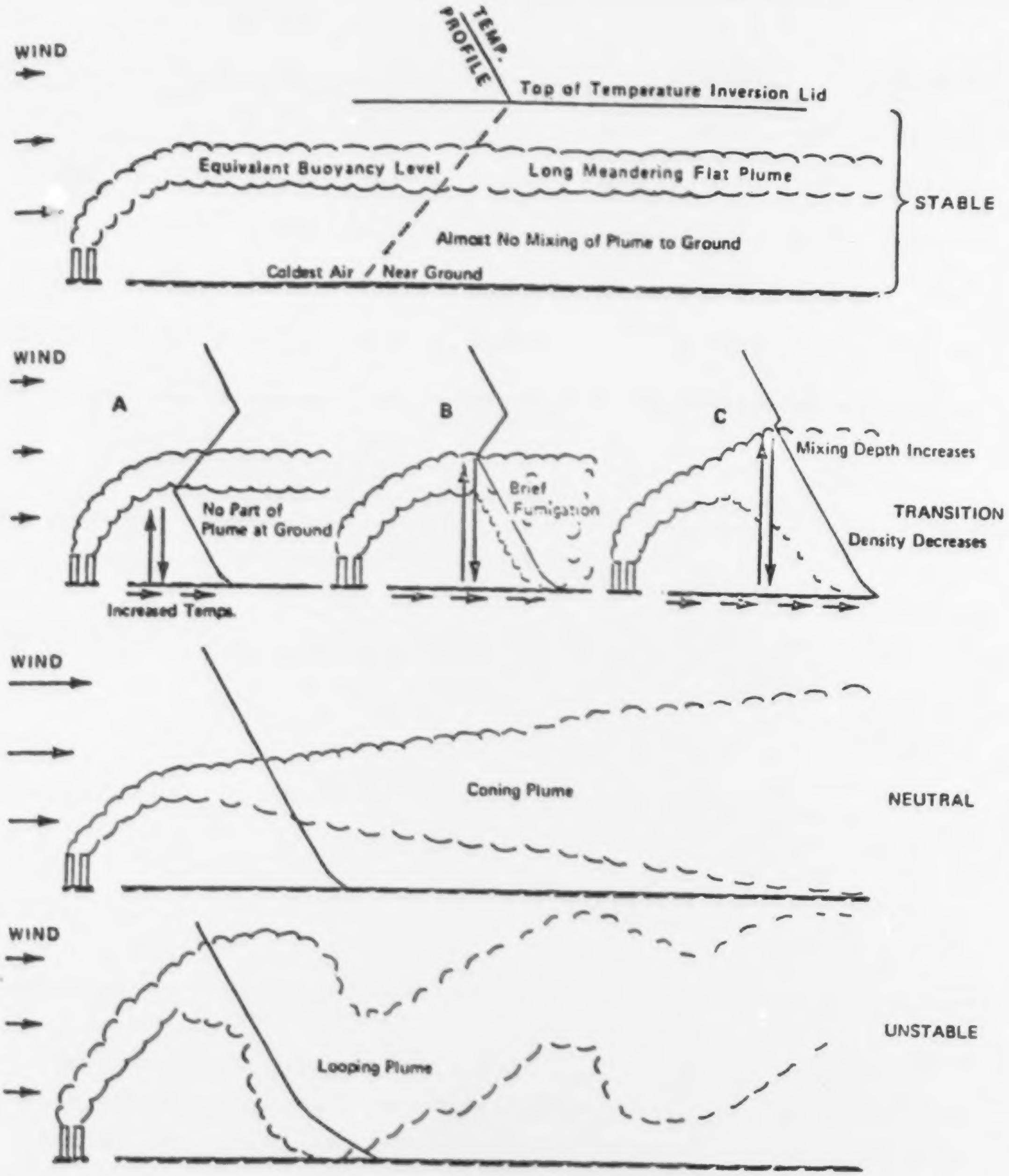
WIND
TEMP. PROFILE
Top of Temperature Inversion Lid
Equivalent Buoyancy Level
Long Meandering Flat Plume
STABLE
Almost No Mixing of Plume to Ground
Coldest Air / Near Ground
WIND
A
B
C
No Part of Plume at Ground
Brief Fumigation
Mixing Depth Increases
TRANSITION
Density Decreases
Increased Temps.
WIND
Coning Plume
NEUTRAL
WIND
Looping Plume
UNSTABLE

Figure A-V-1. Schematic diagrams of typical stack plume patterns under four identifiable stability categories (3)

TABLE A-V-3. RELATIVE FREQUENCY OF OCCURRENCE, FIVE STABILITY CLASSES BY SEASON (%)

		Class				
Season	Months	A	B	C	D	E
Winter	Dec., Jan., Feb.	0.0	1.4	6.7	64.4	27.5
Spring	Mar., Apr., May	0.7	5.9	10.1	53.5	29.8
Summer	June, July, Aug.	2.8	15.4	16.2	29.5	36.1
Fall	Sept., Oct., Nov.	0.0	5.1	9.5	46.9	38.5
Annual	All months	0.9	7.0	10.6	48.5	33.0

TABLE A-V-4. RELATIVE FREQUENCY OF OCCURRENCE, FIVE STABILITY CLASSES BY WIND SPEED (%)

	Wind speed (meters per second)					
Stability class	0.0-1.5	2.0-3.0	3.5-5.0	5.5-8.0	8.5-11.0	11.0
A	0.34	0.56	-----	-----	----	----
B	1.90	3.22	1.84	-----	----	----
C	1.56	2.33	5.73	0.99	0.04	----
D	2.58	9.25	18.26	16.21	2.03	0.13
E	14.89	13.29	4.83	-----	----	----
	21.27	28.65	30.66	17.20	2.07	0.13

Figures A-V-2, A-V-3, and A-V-4 are generalized plots generated by the STAR program showing the pollutant dispersion expected for various atmospheric stability conditions for a 213 meter stack in White County, Illinois. These dispersion characteristics can be used to calculate the specific atmospheric concentrations at specific downwind distances of the numerous specific air pollutants mentioned

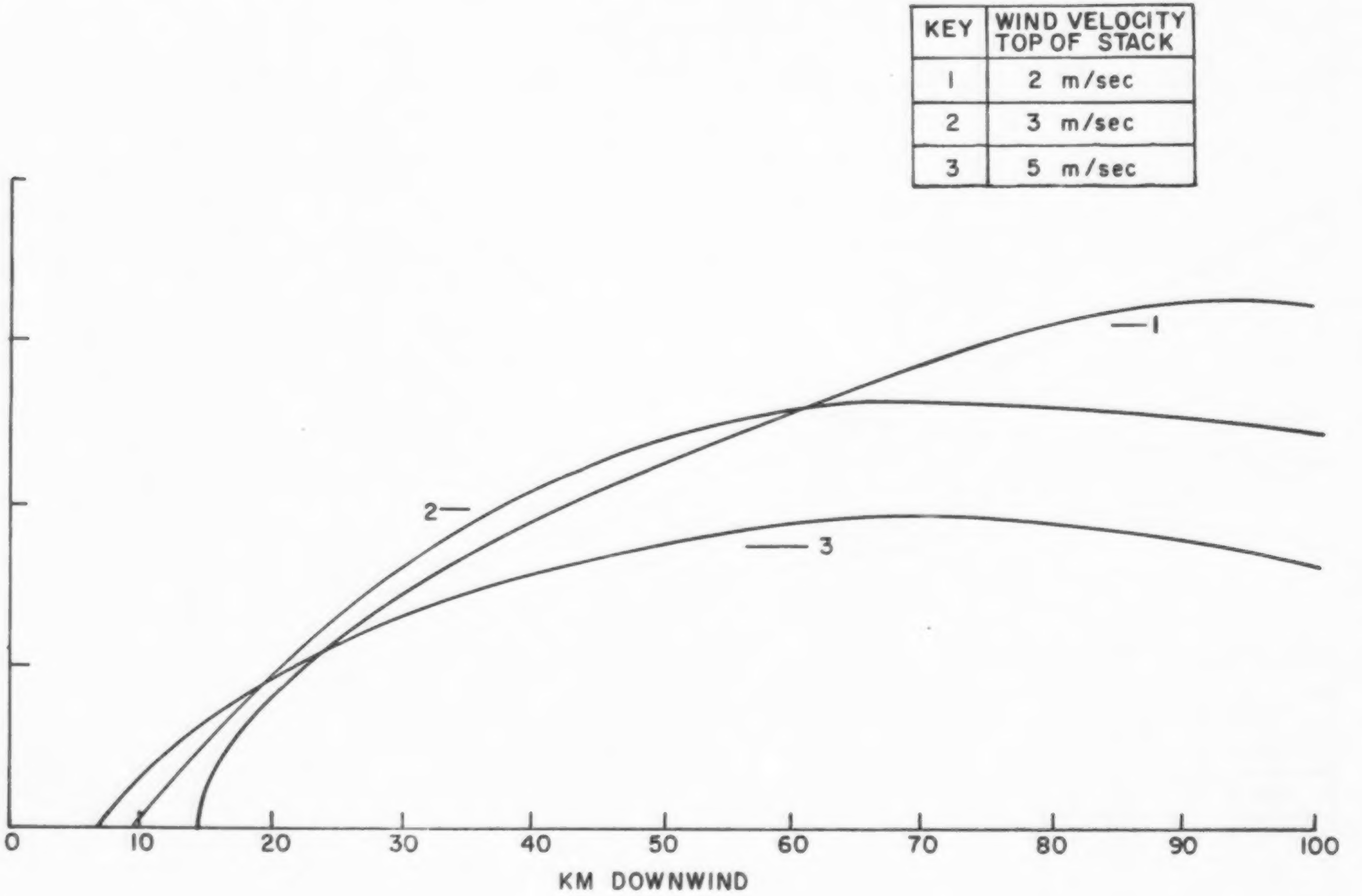

Figure A-V-2. Generalized plot of stack emitted pollutant concentration near ground at various wind speeds for STAR stability class E for a 213 meter stack (3)

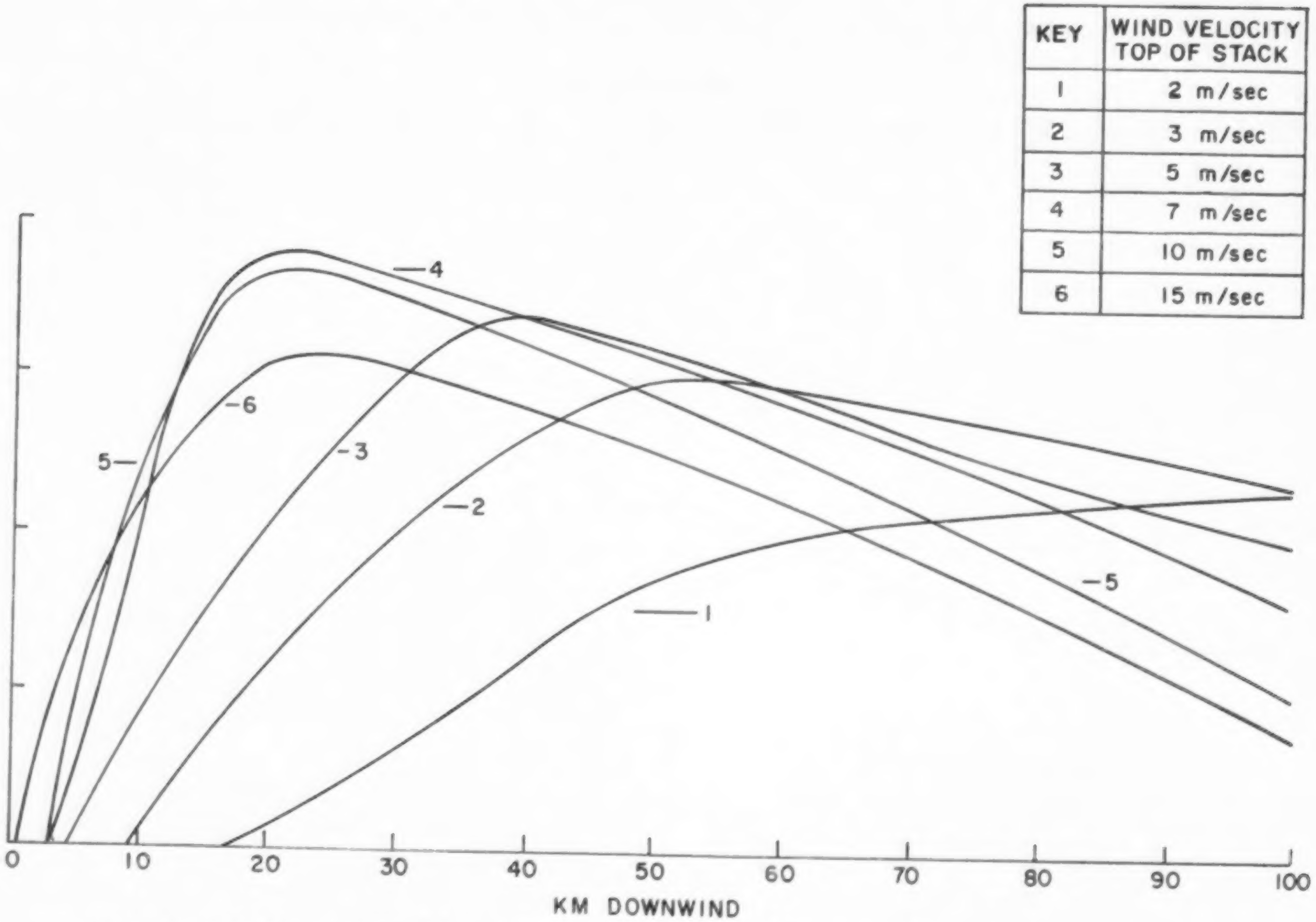

Figure A-V-3. Generalized plot of stack emitted pollutant concentration near ground at various wind speeds for STAR stability class D for a 213 meter stack (3)

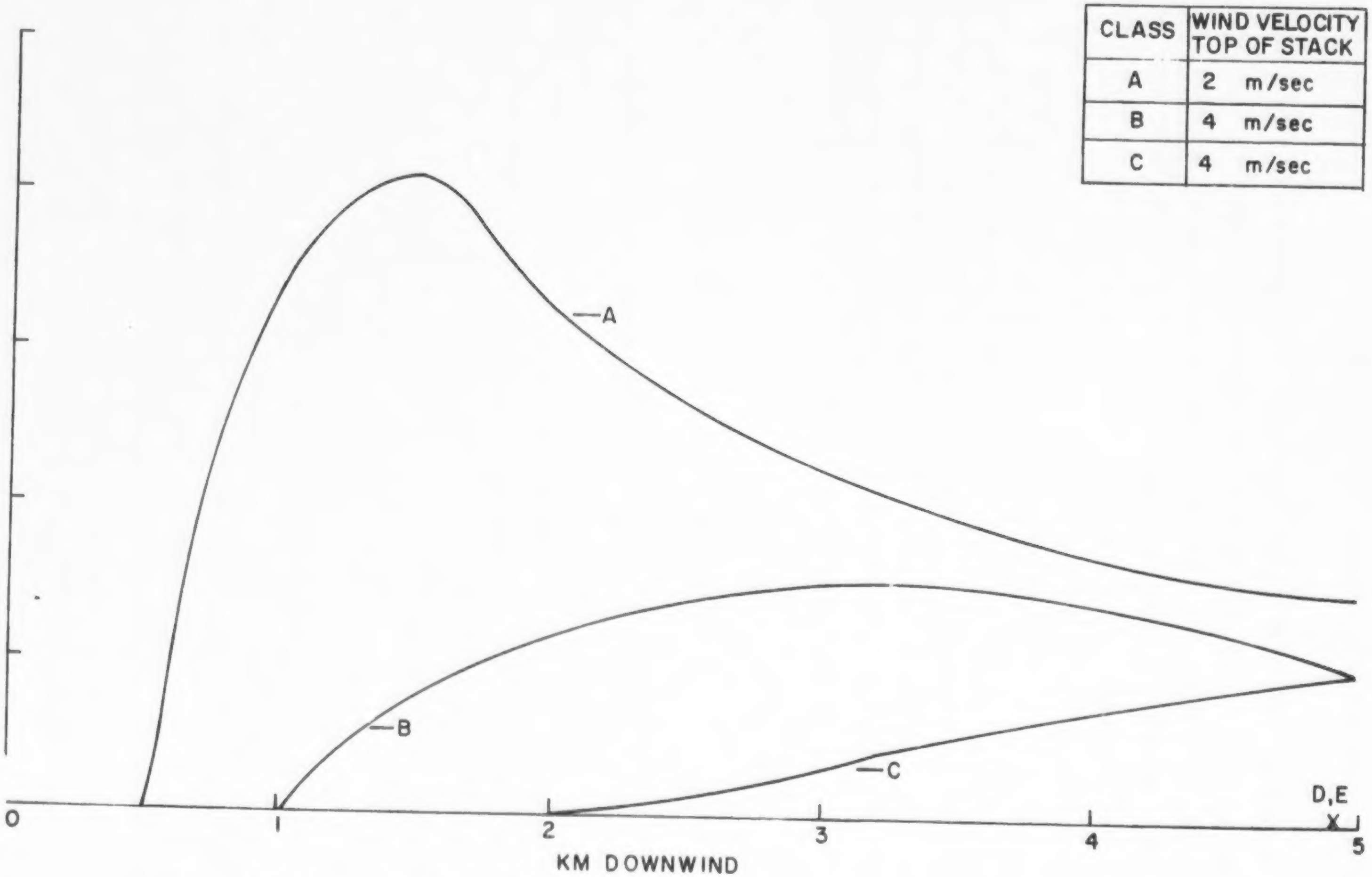

Figure A-V-4. General plot of stack emitted pollutant concentration near ground under all STAR stabilities at near critical wind speeds for a 213 meter stack (3) in Chapter 3 of this report. A wind speed of 15.0 meters/sec is approximately equal to 33.6 mph.

Downwash of the plume into the low-pressure region in the wake of a stack can occur if the exit velocity is too low. If the stack is too low, the plume can be caught in the wake of associated buildings. A similar effect can also occur in the wake of a terrain feature. Two rules of thumb are generally accepted as proper methods for eliminating downwash. One, if the exit velocity from the stack is greater than 1.5 times the average wind speed at the top of the stack, downwash is slight. Two, if a stack is built at least 2.5 times the height of surrounding buildings and designed with sufficient exit velocity to avoid downwash, the plume is normally carried above the region of downflow in the wake of the building.

A-V.1.1.2 Groundwater Hydrologic Factors

A-V.1.1.2.1 Aquifer Recharge and Discharge (4)

Water infiltrates the ground under the influence of gravity, moving first through an unsaturated zone known as the "zone of aeration." Passing downward, the water arrives at the zone of saturation referred to as groundwater. Figure A-V-5 illustrates the relationships within the hydrologic system.

The type of aquifer underlying the site area is important in terms of evaluating the degree to which contamination is likely to occur. The two major types of aquifers are: unconfined or water-table aquifers, and confined or artesian aquifers. Less permeable zones are called aquitards or confining layers (see Figure A-V-5). When an aquifer is unconfined, the water is under atmospheric pressure. The

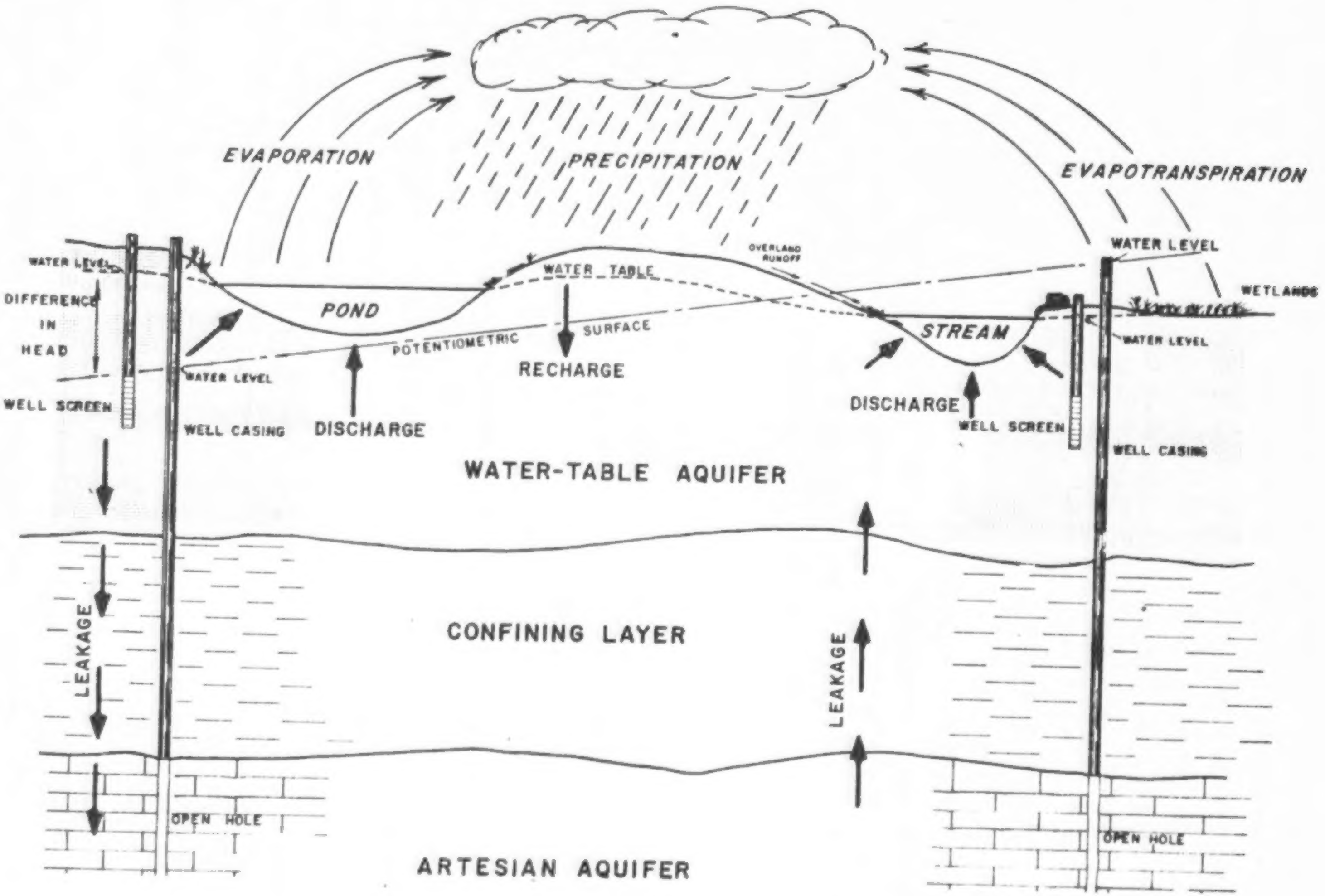
EVAPORATION
PRECIPITATION
EVAPOTRANSPIRATION
WATER LEVEL
DIFFERENCE IN HEAD
WELL SCREEN
WATER LEVEL
WELL CASING
POND
DISCHARGE
WATER TABLE
POTENTIOMETRIC SURFACE
RECHARGE
OVERLAND RUNOFF
STREAM
DISCHARGE
WATER LEVEL
WETLANDS
WATER LEVEL
WELL SCREEN
WELL CASING
WATER-TABLE AQUIFER
CONFINING LAYER
LEAKAGE
LEAKAGE
OPEN HOLE
OPEN HOLE
ARTESIAN AQUIFER

Figure A-V-5. Illustration of relationships within the hydrologic system (4) upper surface of the aquifer is known as the water table and is free to rise and fall with changes in volume of stored water. Confined or artesian aquifers are bounded below by geologic formations of relatively low permeability, and separated from the zone of aeration above or from shallow aquifers by geologic formations of low permeability.

The mechanism of recharge differs between the water table aquifer and the artesian aquifer. The principal source of natural recharge to a water table aquifer is precipitation. Perennial through-flowing streams can also be areas of recharge to or discharge from water table aquifers. An artesian aquifer, however, does not receive recharge everywhere uniformly, but is recharged in one or more general areas.

Groundwater is constantly moving from a point of recharge toward a point of discharge. If a particular region is a recharge area, the recharging water exerts a stress on the aquifer in the form of increased hydrostatic head. This head seeks release in areas of low head, which are designated discharge areas. Thus, movement of groundwater is from regions of high hydrostatic head toward those of low hydrostatic head. Head differences can be induced artificially by pumping wells. As water is withdrawn from a well, a hydraulic gradient is produced, which causes water to move toward the well. A cone-shaped depression in the water table or potentiometric surface is produced (Figure A-V-6).

A-V.1.1.2.2 Hydrogeologic Conditions Affecting Groundwater Contamination (4)

The rate at which water percolates through the ground is highly dependent on soil and bedrock properties as well as other conditions. Unlike the rapid dissipative rates

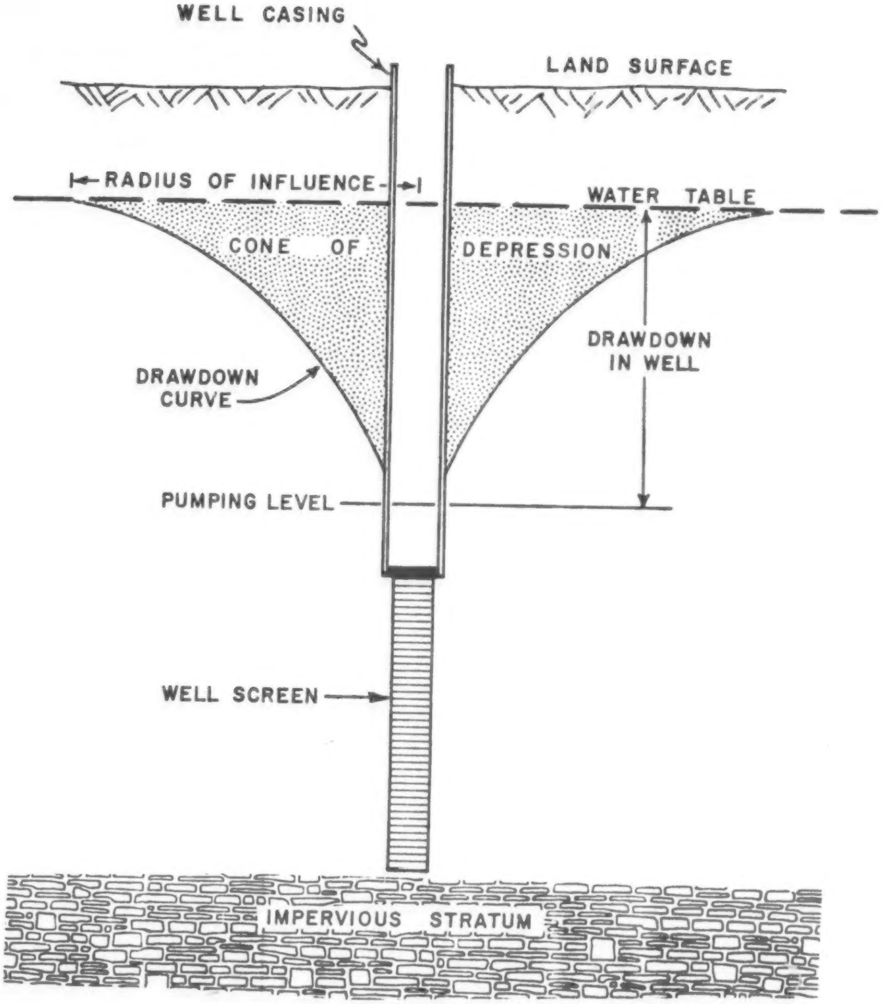
WELL CASING
LAND SURFACE
RADIUS OF INFLUENCE
WATER TABLE
CONE OF DEPRESSION
DRAWDOWN IN WELL
DRAWDOWN CURVE
PUMPING LEVEL
WELL SCREEN
IMPERVIOUS STRATUM

Figure A-V-6. Cone of depression created by pumping in a water-table aquifer (4) characteristic of surface waters, groundwater contamination tends to move very slowly through the soils and aquifers, maintaining a bulb-like mass.

Two related parameters are commonly used in dispersion studies. The first, dispersivity, may be described as the inherent capability of the aquifer to cause disperson. Dispersivity multiplied by groundwater flow velocity gives the dispersion coefficient, which is the dynamic equivalent under actual aquifer conditions. Both are given for longitudinal (in the direction of groundwater flow) and transverse directions.

The rate of groundwater movement within an aquifer is obviously of great importance. It is governed by the hydraulic gradient and aquifer permeability, the latter of which varies far more widely than any other physical property encountered in contamination studies. The U.S. Geological Survey has determined permeabilities for a gravel through which, under a gradient of 2 m/km, water would move at the rate of 18 m/day, and for a clay through which, under the same gradient, the rate of movement would be 0.3 m in about 30,000 years. Flow rates in most aquifers, however, range from a few meters per day to a few meters per year.

Although groundwater travels through an aquifer slowly, it is in constant motion and must eventually discharge to the surface because all aquifer systems are being recharged to some degree. In humid areas, discharge of contaminants is relatively quick for shallow water-table aquifers and slow for deep artesian aquifers. In arid regions, recharge and discharge are so slow that some aquifers can actually be considered sinks similar to the ocean. Points of discharge include wells and springs used for water supply, and surface-water bodies such as rivers and lakes.

The configuration of contaminant entry into, and movement within the underground is unique for each individual source of contamination. However, typical flow patterns of groundwater contaminants for a variety of common situations can be described.

Where the local hydrogeology is known, paths of probable contaminant movement can be defined. Site evaluations, including tests to determine the permeability and hydraulic gradient of the area, would be utilized to ascertain the movement. The permeability of the soils affects the rate at which leachate will percolate into the groundwater. As described in Chapter 2, the coefficient of permeability of the site soils can be used to calculate the containment time or seepage rate for landfilled wastes at a particular site. In order to make such determinations, however, field samples and studies would be required for the specific site. Rates of contaminant movement are based on groundwater flow rates, chemical interactions with aquifer materials, and changes in water chemistry. Thus, contaminants travel at velocities equal to, greater than, or less than that of average groundwater flow. The adsorptive potential of a soil affects the movement of a contaminant through the soil column. In general, the more finely divided the soils, the greater the adsorptive capacity. To estimate the soil adsorptive potential at the site, however, knowledge of the specific soils involved would be required.

The mechanisms of groundwater contamination are illustrated by the flow paths of contaminants for a variety of situations. The flow of groundwater within underground formations affects the sizes and shapes of typical zones of contaminated groundwater. An idealized flow pattern, shown in Figure A-V-7, illustrates that the contaminated water moves to its discharge area by a definite route, and is not

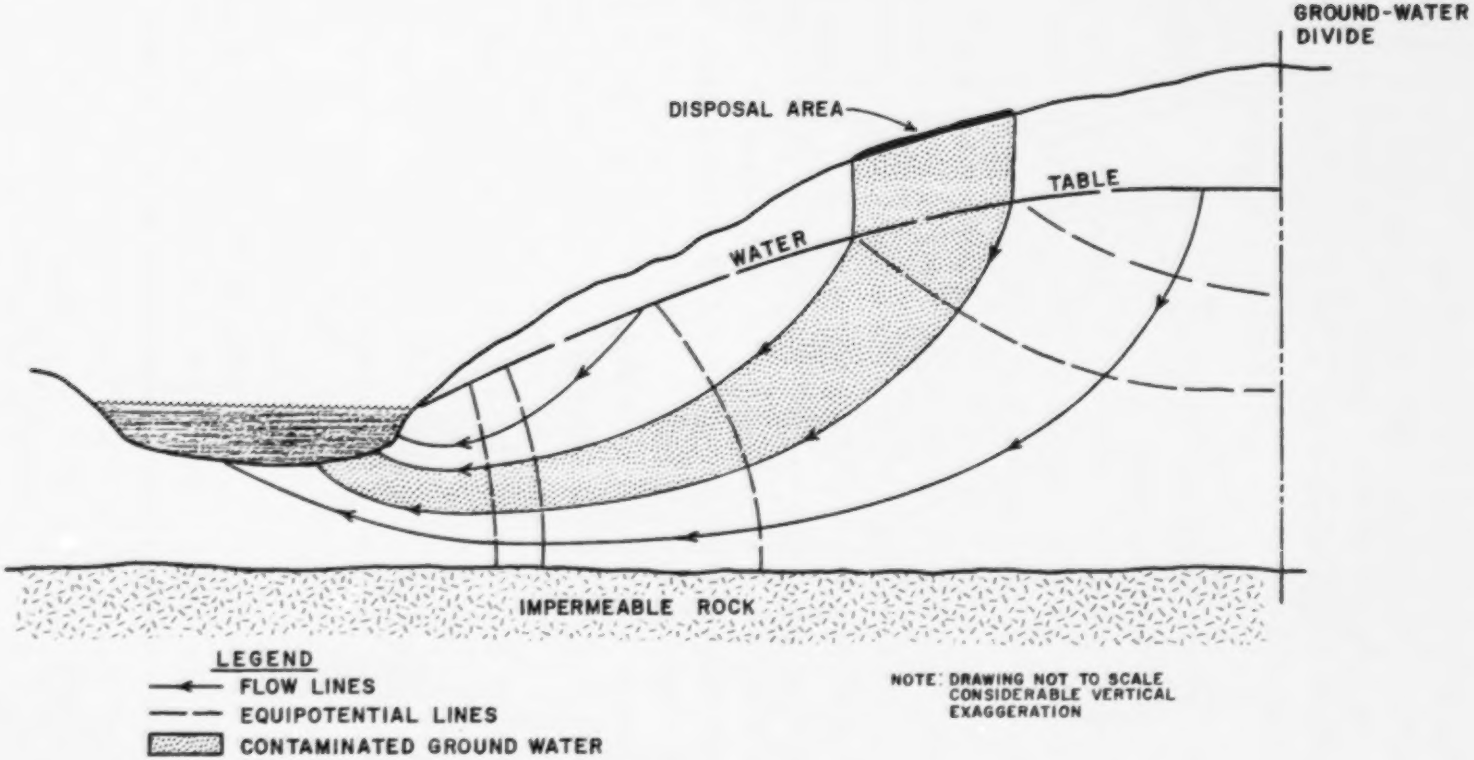
GROUND-WATER DIVIDE
DISPOSAL AREA
TABLE
WATER
IMPERMEABLE ROCK
LEGEND
FLOW LINES
EQUIPOTENTIAL LINES
CONTAMINATED GROUND WATER
NOTE: DRAWING NOT TO SCALE CONSIDERABLE VERTICAL EXAGGERATION

Figure A-V-7. Flow in a water-table aquifer (humid region) (4) (as is often imagined) subject to dilution by the entire body of groundwater lying between the disposal area and the area of discharge.

A-V.1.2 Ranking

The ranking of many of the elements with respect to their absolute toxicity can be found in Tables A-V-5 and A-V-6. Table A-V-5 is a ranking system which simply counts the number of plus signs in Tables 5-11 and 5-12. This number is then called the Hittman Ranking System Number. The MEG Hazard Potentials (Table A-V-6) derived by use of the MEG methodology are obtained by a system which performs mathematical manipulations on the MEGs. The former system is partially inadequate since, for example, the syndrome "carcinogenesis" is ranked equally with "nausea" while the latter system is partially inadequate since it neglects all chronic toxic effects (except carcinogenesis) such as (chronic) brain and nervous system pathology, behavioral modification, reproductive effects, and shortened life span, et cetera. In spite of the fact that these two types of inadequacies seem contradictory, the ranking of the absolute toxicities of elements using these two systems are remarkably consistent (see Table A-V-6).

A "composite ranking number" was calculated according to the following formula:

$$\text{Composite Ranking Number} = \frac{\frac{\text{Hittman Ranking} \times 30}{46} + \text{MEG Hazard Potential}}{2}$$

This formula normalizes Hittman Ranking Numbers (maximum 46) to MEG Hazard Potentials (maximum 30). These numbers, found in Table A-V-6, have been calculated for all elements on which information is available. Since the inherent

TABLE A-V-5. HITTMAN RANKING SYSTEM FOR POTENTIAL TOXICITY FOR VARIOUS ELEMENTS[a]

Element	Number of "Plus" (+) Signs, Both Tables	Number of "Plus" (+) Signs, Human Pathology Table	Number of "Plus" (+) Signs, Animal Pathology Table
Cadmium	46	16	30
Mercury	31	13	18
Lead	31	9	22
Arsenic	29	14	15
Selenium	29	8	21
Thallium	28	12	16
Nickel	26	8	18
Beryllium	25	12	13
Copper	23	3	20
Zinc	20	1	19
Antimony	19	6	13
Chromium	15	5	10
Fluorine, Manganese	7	5	2
Sulfur (Hydrogen Sulfide)	6	6	0
Nitrogen (Nitrate/Nitrite)	6	3	3
Iron	6	1	5
Cobalt	5	0	5
Vanadium	2	2	0

[a] This ranking is somewhat arbitrary. As an example, the syndrome "carcinogenosis" is given equal weight with "nausea". Inclusion in this list indicates that an element is of environmental concern regardless of its relative rank. Exclusion of a substance does not imply that it is safe for the environment in all forms.

TABLE A-V-6. COMPARISON OF THE ABSOLUTE TOXICITY POTENTIAL OF TRACE ELEMENTS AS ESTIMATED BY THE HITTMAN SYSTEM AND THE MEG SYSTEM AND ESTIMATION OF THE RELATIVE TOXICITY OF THESE MATERIALS IN ILLINOIS NO. 6 COAL

Element	Hittman Ranking System	MEG Hazard Potential	Hittman Ranking X Avg. Conc. Ill. #6 Coal	Hittman Ranking X Max. Conc. Ill. #6 Coal	MEG Hazard Potential X Avg. Conc. Ill. #6 Coal	MEG Hazard Potential X Max. Conc. Ill. #6 Coal	Composite Ranking X Avg. Conc. Ill. #6 Coal	Composit Ranking X Max. Conc. Ill. #6 Coal
*Cadmium	46	30	180.	3,000.	120.	2,000.	120.	2,000.
*Mercury	31	30	5.6	16.	5.4	16.	4.5	13.
*Lead	31	22	840.	6,500.	600.	4,600.	570.	4,400.
*Arsenic	29	25	170.	930.	150.	800.	130.	700.
*Selenium	29	26	64.	220.	57.	200.	49.	170.
*Thallium	28	20	19.	36.	13.	26.	13.	25.
*Nickel	26	26	570.	1,100.	570.	1,100.	470.	900.
*Beryllium	25	30	38.	98.	45.	120.	35.	90.
*Copper	23	20	300.	600.	260.	520.	230.	460.
*Zinc	20	12[d]	8,400.	1.1x10^5	5,000.	6.4x10^4	5,300.	6.6x10^4
*Antimony	19	26[a]	19.	93.	25.	130.	19.	94.
*Chromium	15	30	300.	900.	600.	1,800.	400.	1,200.
Manganese	7	15	370.	1,300.	800.	2,700.	520.	1,800.
Fluorine	7	Not ranked	440.	840.	---	---	---	---
Sulfur (Hydrogen sulfide)	6	12[d]	2.1x10^5	3.9x10^5	4.2x10^5	7.7x10^5	2.8x10^5	5.1x10^5
Nitrogen (Nitrate/Nitrite)	6	Not ranked	7.7x10^4	1.1x10^5	---	---	---	---
Iron	6	Not ranked	1.1x10^5	2.1x10^5	---	---	---	---
Cobalt	5	24	33.[e]	75.[e]	79.[e]	180.[e]	50.[e]	114.[e]
Vanadium	2	16	66.	110.	530.	880.	290.	480.
Bismuth	Not ranked[b]	20	---	---	---	---	---	---
Uranium	Not ranked[b]	20	---	---	32.[e]	90.[e]	---	---
Lithium	Not ranked[b]	16	---	---	---	---	---	---
Barium	Not ranked[b]	16	---	---	1,800.	1.2x10^4	---	---
Tellurium	Not ranked[b]	16	---	---	---	---	---	---
Germanium	Not ranked[b]	16	---	---	90.	420.	---	---
Gallium	Not ranked[b]	15	---	---	47.	68.	---	---
*Silver	Not ranked[b]	14	---	---	0.42	0.84	---	---
Potassium	Not ranked[c]	12[d]	---	---	2.0x10^4	2.9x10^4	---	---
Magnesium	Not ranked[c]	12[d]	---	---	6,100.	1.3x10^4	---	---
Strontium	Not ranked[c]	12[d]	---	---	430.	1,600.	---	---
Boron	Not ranked[c]	12[d]	---	---	1,600.	2,800.	---	---
Aluminum	Not ranked[c]	12[d]	---	---	1.6x10^5	3.6x10^5	---	---
Titanium	Not ranked[c]	12[d]	---	---	8,400.	1.8x10^4	---	---
Molybdenum	Not ranked[c]	12[d]	---	---	110.	350.	---	---
Tungsten	Not ranked[c]	12[d]	---	---	8.4	25.	---	---
Nitrogen (Ammonia)	Not ranked[c]	8[d]	---	---	1.0x10^5	1.4x10^5	---	---
Scandium	Not ranked[c]	8[d]	---	---	21.	33.	---	---

[*] On EPA's list of 65 toxic substances.

[a] Antimony trioxide. Elemental antimony ranked at 20.

[b] Too little information was available to rank these elements.

[c] Not considered a sufficient environmental risk.

[d] Hazard potentials less than 13 are not considered to be associated with hazardous material.

[e] Based on chemical rather than radiological effects.

deficiencies of the two ranking systems seem to partially cancel each other, the composite ranking number may be the best indicator of possible environmental toxicity in absolute terms.

However, many of the elements which have been ranked high using either ranking system are present in minute amounts in Illinois No. 6 coal. For example, cadmium is ranked highest in absolute toxic potential, using both the Hittman System (Table A-V-5) and the MEG Hazard Potential (Table A-V-6). However, the average concentration of cadmium in Illinois No. 6 coal is less than 4 ppm, while the range is from less than 0.5 to 65 ppm (Chapter 3). As another example, mercury is ranked second highest in absolute toxic potential using both the Hittman System and the MEG Hazard Potential; however, the average concentration of mercury in Illinois No. 6 is 0.18 ppm with a range of 0.04 to 0.52 ppm. On the other hand, aluminum is relatively innocuous (unranked by the Hittman System, a Hazard Potential of 12 by the MEGs system); yet, aluminum is relatively abundant in Illinois No. 6 coal (average: 13,500 ppm; range 10,000 to 30,400 ppm). Since aluminum is known to damage living systems when present at higher concentrations, the environmental impact of aluminum may be greater than the environmental impact of cadmium or mercury. There are approximately 3,500 times more aluminum than cadmium, and approximately 75,000 times more aluminum than mercury in Illinois No. 6 coal. The lowest the aluminum/cadmium ratio can be is the minimum concentration of aluminum found over the maximum concentration of cadmium found, or approximately 150. The lowest the aluminum/mercury ratio can be is 20,000.

In order to provide a more realistic ranking of the relative environmental hazard potential of using Illinois No. 6 coal, the values provided as indices of absolute toxicity were multiplied by the concentration of the individual pollutant in Illinois No. 6 coal. The results of these calculations are given in Table A-V-6. Since the deficiencies of the Hittman System and the MEG System tend to cancel each other, the calculation using the Composite Ranking Number may be the most significant indicator of possible environmental hazard. The elements and compounds have been ranked according to the Relative Hazard Potential using the Composite Ranking Number when both the MEG Hazard Potential and the Hittman Ranking Number were available (thus, making calculation of the Composite Ranking Number possible). When either the Hittman Ranking Number or the MEG Hazard Potential was unavailable, the Relative Hazard Potential was calculated using the available ranking number.

A-V.1.3 Characteristics of Chemical Pollutants

Tables A-V-7, A-V-8, and A-V-9 show the solubility product constants (pK_{sp}'s) for elements, inorganic compounds, and complexes associated with SRC technology. In general, information of this type can be used to predict if an element in an effluent stream will be in a soluble form or in an insoluble form. The presence of an element in a soluble form implies that the element will travel at the same rate as that of the receiving water, and thus will be more subjected to exposure, absorption, and assimilation by aquatic biota. Elements in insoluble forms are more likely to be absorbed with sediments. However, "soluble" is a relative term and significant concentrations of solvated ions can occur for the more toxic elements, even if they occur as insoluble forms.

Unfortunately, the solubility characteristics of the elements can be changed from the behavior predicted in Tables A-V-7, A-V-8, and A-V-9 by environmental interactions.

TABLE A-V-7. SOLUBILITY OF "INSOLUBLE" INORGANIC SUBSTANCES (5,6,7,8,9,10)

Compound	Formula	pKsp
Aluminum borate	$Al_2O_3 \cdot B_2O_3$	ins.
Aluminum boride	AlB_{12}	ins.
Aluminum fluosilicate	$2AlFO \cdot SiO_2$	ins.
Aluminum metaphosphate	$Al(PO_3)_3$	ins.
Aluminum hypophosphite	$Al(PO_2H_2)_3$	ins.
Aluminum silicate	$Al_2O_3 \cdot SiO_2$ or $3Al_2O_3 \cdot 2SiO_2$	ins.
Ammonium calcium arsenate	$NH_4CaAsO_4 \cdot 6H_2O$ $(=NH_4^+ + CaAsO_4^-)$	6.4
Ammonium calcium phosphate	$NH_4CaPO_4 \cdot 7H_2O$	ins.
Ammonium magnesium arsenate	$NH_4MgAsO_4 \cdot 6H_2O$ $(=NH_4^+ + Mg^+ + AsO_4^=)$	8.6-9.2
Ammonium magnesium phosphate	$NH_4MgPO_4 \cdot 6H_2O$ $(=NH_4^+ + Mg^+ + PO_4^=)$	9.1-9.3
Ammonium manganese phosphate	$NH_4MnPO_4 \cdot H_2O$ $(=NH_4^+ + Mn^+ + PO_4^=)$	11.3-7.7
Antimony hydride	SbH_3	4.5
Antimony iodosulfide	$SbSI$	ins.
Antimony (III) oxychloride	$SbOCl$ or $Sb_4O_5Cl_2$	ins.
Arsenic hemiselenide	As_2Se	ins.
Arsenic selenide	As_2Se_3	ins.
Arsenic pentaselenide	As_2Se_5	ins.
Arsenic triselenide	As_2Se_3	ins.
Barium hexaboride	BaB_4	ins.
Barium biphosphate	$BaHPO_4$	6 to 29
Barium bromate	$Ba(BrO_3)_2 \cdot H_2O$	2.0-5.8
Barium chromate	$BaCrO_4$	9.5 to 9.9
Barium fluogallate	$Ba_3(GaF_6)_2 \cdot H_2O$	ins.
Barium fluorosilicate	$BaSiF_6$ $(=Ba^{++} + SiF_6^=)$	5.0-6.5
Barium molybdate	$BaMoO_4$ $(=Ba^{++} + MoO_4^=)$	7.4
Barium pyrophosphate	$Ba_2P_4O_7$	10.4
Barium selenate	$BaSeO_4$	4.6-6.8
Barium metasilicate	$BaSiO_3$	4.6
Barium sulfite	$BaSO_3$	6.1-8.1
Barium thiosulfate	BaS_2O_3	4.2
Beryllium carbonate, basic	$BiCO_3 + BaOH$	ins.
Bismuth aluminate	$Bi_2(Al_2O_4)_3$	ins.
Bismuth carbonate, basic	$Bi_2O_2CO_3$	ins.
Bismuth dichromate, dibasic	$(BiO)_2Cr_2O_7$	ins.
Bismuth gallate, basic	$Bi(OH_2)C_7H_5O_5$ (approximately)	ins.
Bismuth iodide, oxide	$BiOI$	ins.
Bismuth nitrate, basic	$BiONO_3 \cdot H_2O$	ins.
Bismuth oxybromide	$BiOBr$	ins.

(continued)

TABLE A-V-7. (continued)

Compound	Formula	pKsp
Bismuth oxychloride	$BiOCl$	ins.
Bismuth oxyfluoride	$BiOF$	ins.
Bismuth oxyiodide	$BiOI$	ins.
Bismuth selenide	Bi_2Se_3	ins.
Bismuth silicate	$2Bi_2O_3 \cdot 3SiO_2$	ins.
Bismuthic acid	$HBiO_3$	ins.
Bromoform	$CHBr_3$ (no dissociation)	2.3
Boron carbide	B_4C	ins.
Boron nitride	BN	ins.
Boron phosphide	BP	ins.
Cadmium arsenide	Cd_3As_2	ins.
Cadminum chromite	$CdCr_2O_4$	ins.
Cadmium selenide	$CdSe$	ins.
Cadmium telluride	$CdTe$	ins.
Cadmium tungstate	$CdWO_4$	5.7
Tricalcium aluminate	$Ca_3Al_2O_4$	ins.
Calcium biphosphate	$CaHPO_4$	4.7-5.5
Calcium boride	CaB_6	ins.
Calcium chromate	$CaCr_2O_4$	ins.
Monocalcium ferrite	$CaO \cdot Fe_2O_3$	ins.
Calcium magnesium carbonate	$CaCO_3 \cdot MgCO_3$ ($=Ca^{++} + Mg^{++} + 2CO_3^{=}$)	11.0
Calcium magnesium metasilicate	$CaO \cdot MgO \cdot 2SiO_2$	ins.
Calcium molybdate	$CaMoO_4$	ins.
Calcium hypophosphate	$CaP_2O_6 \cdot 2H_2O$	ins.
Calcium metaphosphate	$Ca(PO_3)_2$	ins.
Calcium molybdate	$CaMoO_4$	ins.
Calcium pypophosphate	$Ca_2P_2O_7$	ins.
Calcium orthoplumbate	Ca_2PbO_4	ins.
Calcium metasilicate	$CaSiO_3$	6.2
Calcium silicide	$CaSi$	ins.
Calcium tungstate	$CaWO_4$	4.3-10.8
Calcium silicate	Ca_2SiO_4 and Ca_3SiO_5	ins.
Calcium sulfite	$CaSO_3$	7.1-8.3
Carbon tetrachloride	CCl_4 (no dissociation)	2.5
Carbon tetrabromide	CBr_4 (no dissociation)	2.1
Dicarbon tetrabromide	C_2Br_4	ins.
Carbon tetraiodide	CI_4	ins.
Carbon diselenide	CSe_2	ins.
Carbon selenide, sulfide	$CSeS$	ins.
Carbon disulfide	CS_2	2.2 g/l
Carbon monosulfide	CS	ins.

(continued)

TABLE A-V-7. (continued)

Compound	Formula	pKsp
Cerium hexaboride	CeB_6	ins.
Cerium oxychloride	$CeOCl$	ins.
Cerium silicide	$CeSi_2$	ins.
Cesium aluminum sulfate	$CsAl(SO_4)_2 \cdot 12H_2O\ (=Cs^+ + Al^{+3} + 2SO_4^{-2})$	0.5-8.9
Cesium chloraurate	$CsAuCl_4$	1.4-11.8
Cesium chloroplatinate	Cs_2PtCl_6	20.3-31.0
Cesium gallium sulfate	$CsGa(SO_4)_2 \cdot 12H_2O$	6.8
Cesium gallium selenate	$CsGa(SeO_4)_2 \cdot 2H_2O$	4.9
Cesium permanganate	$CsMnO_4$	2.6-4.8
Cesium mercury bromide	$CsBr \cdot 2HgBr_2$	8.07 g/1
Cesium mercury chloride	$CsCl \cdot HgCl_2$	14.4 g/1
Cesium vanadium sulfate	$VCs(SO_4)_2 \cdot 12H_2O$	8.4
Chromium monarsenide	$CrAs$	ins.
Chromium monobromide	CrB	ins.
Trichromium dicarbide	Cr_3C_2	ins.
Chromium carbonyl	$Cr(CO)_6$	ins.
Chromium nitride	CrN	ins.
Chromium pyrophosphate	$Cr_4(P_2O_7)_3$	ins.
Chromium monophosphide	CrP	ins.
Hexaureachromium (III) fluosilicate	$(Cr(CON_2H_4)_6)_2 \cdot (SiF_6)_3 \cdot 3H_2O$	10.0
Chloropentammine chromium chloride	$(Cr(NH_3)_5Cl)Cl_2\ (=(Cr(NH_3)_5Cl)^{++} + 2Cl^-)$	4.1
Cobalt aluminate	ca. $CoAl_2O_4$	ins.
Cobalt arsenide	CO_2As	ins.
Cobalt tetracarbonyl	$(Co(CO)_4)_2$ or $Co_2(CO)_8$	ins.
Cobalt nitrosylcarbonyl	$Co(NO)(CO)_3$	ins.
Cobalt phosphide	Co_2P	ins.
Cobalt (II) orthosilicate	Co_2SiO_4	ins.
Cobalt (II) sulfite	$CoSO_3 \cdot 5H_2O$	ins.
Cobalt (II) tungstate	$CoWO_4$	ins.
Hexamminecobalt (III) sulfate	$(Co(NH_3)_6)_2(SO_4)_3 \cdot 5H_2O(=2(Co(NH_3)_6)^+ + SO_4^=)$	6.5
Aquapentamminecobalt (III) sulfate	$(Co(NH_3)_5H_2O)_2(SO_4)_3 \cdot 2H_2O$	7.0
Chloropentamminecobalt (III) chloride	$(Co(NH_3)_5Cl)Cl_2$	4.8
Trinitrotriamminecobalt	$Co(NH_3)_3(NO_2)_3(=(CO(NH_3)_3)^{+3} + 3NO_2^-)$	7.2
Copper amine azide	$Cu(NH_3)_2(N_3)_2$	ins.
Copper (II) diamminedichlorid	$Cu(NH_3)_2Cl_2$	ins.
Copper (I) azide	$CuN_3\ (=Cu^+ + N_3^-)$	8.3
Copper (II) azide	$Cu(N_3)_2\ (=Cu^{++} + 2N_3^-)$	9.2
Copper trioxybromide	$CuBr_2 \cdot 3Cu(OH)_2$	ins.

(continued)

TABLE A-V-7. (continued)

Compound	Formula	pKsp
Copper (II) chlorate, basic	$Cu(ClO_3)_2 \cdot 3Cu(OH)_2$	ins.
Copper chromate	$CuCrO_4$	ins.
Copper (II) chromate, basic	$CuCrO_4 \cdot 2CuO \cdot 2H_2O$	ins.
Copper (I) chromite	$Cu_2Cr_2O_4$	ins.
Copper hydride	CuH	ins.
Copper (II) trihydroxychloride	$CuCl_2 \cdot 3Cu(OH)_2$	ins.
Copper (II) trihydroxynitrate	$Cu(NO_3)_2 \cdot 3Cu(OH)_2$	ins.
Copper paraperiodate	Cu_2HIO_6	ins.
Copper mercury iodide	Cu_2HgI_4	ins.
Copper (II) tungstate	$CuWO_4 \cdot 2H_2O$	5.1
Copper (II) nitrite, basic	$Cu(NO_2)_2 \cdot 3Cu(OH)_2$	ins.
Copper (II) hyponitrite, basic	$Cu(NO)_2 \cdot Cu(OH)_2$	ins.
Tricopper phosphide	Cu_3P	ins.
Copper (II) selenide	$CuSe$	ins.
Copper selenite	$CuSeO_3 \cdot 2H_2O$	ins.
Copper (I) sulfite	$Cu_2SO_3 \cdot H_2O$	ins.
Copper (I,II) sulfite, dihydrate	$Cu_2SO_3 \cdot CuSO_3 \cdot 2H_2O$	ins.
Copper (I) thiocyanate	$CuSCN$	8.8
Tetrapyridine copper (II) perrhenate	$(Cu(C_5H_5N)_4)(ReO_4)_2$	6.0
Dysprosium chromate	$Dy_2(Cr_2O_4)_3 \cdot 10H_2O$	7.6
Gallium oxychloride	$GaOCl$	ins.
Germanium hydrides	Ge_3H_8; GeH_4	ins.
Germanium selenide	$GeSe_2$	ins.
Hafnium oxychloride	$HfOCl$	ins.
Hafnium carbide	HfC	ins.
Iron (IV) biphosphate	$Fe(HPO_4)_2$	12.6
Iron (II) biphosphate	$Fe(HPO_4)$	8.3
Iron carbide	FeC	ins.
Iron carbonyl	$Fe_x(CO)_y$	ins.
Iron chromate	$Fe_2(CrO_4)_3$	ins.
Iron (II) chromite	$FeCr_2O_4$	ins.
Iron nitrosyl carbonyl	$Fe(NO)_2(CO)_2$	ins.
Iron (III) pyrophosphate	$Fe_4(P_2O_7)_3 \cdot 9H_2O$	ins.
Diiron phosphite	Fe_2P	ins.
Triiron phosphite	Fe_3P	ins.
Iron (III) hypophosphite	$Fe(H_2PO_2)_3$	9.6
Iron orthosilicate	Fe_2SiO_4	ins.

(continued)

TABLE A-V-7. (continued)

Compound	Formula	pKsp
Lanthanum hexaboride	LaB_6	ins.
Lanthanum molybdate	$La_2(MoO_4)_3$	19.8-21.1
Lead chromate	$PbCrO_4$	13.5-13.8
Lead diantimonate	$Pb_2Sb_2O_7$	ins.
Lead orthoantimonate	$Pb_3(SbO_4)_2$	ins.
Lead azide	PbN_3	6.9-8.7
Lead metaborate	$Pb(BO_2)_2 \cdot H_2O$	ins.
Lead biphosphate	$PbHPO_4$	9
Lead chloride, sulfide	$PbCl_2 \cdot 3PbS$	ins.
Lead chlorite	$Pb(ClO_2)_2$	5.1-7.1
Lead chromate, basic	$PbCrO_4 \cdot PbO$ or $Pb_2(OH)_2CrO_4$	ins.
Lead fluorochloride	$PbFCl$	7.2-8.5
Lead paraperiodate	$PbHIO_5$	ins.
Lead molybdate	$PbMoO_4$	ins.
Lead oxychloride	$PbCl_2 \cdot 3PbO$	0.056-0.7 g/l
	$PbCl_2 \cdot 7PbO$	ins.
	$PbCl_2 \cdot Pb(OH)_2$	0.095 g/l
	$PbCl_2 \cdot 2PbO$	ins.
Lead orthophosphite	$PbHPO_3$	ins.
Lead pyrophosphate	$Pb_2P_2O_7$	ins.
Lead selenate	$PbSeO_4$	ins.
Lead selenide	$PbSe$	ins.
Lead metasilicate	$PbSiO_3$	ins.
Lead orthosilicate	$Pb_2Si_2O_7$	ins.
Lead sulfate, basic	$PbSO_4 \cdot PbO$	0.044 g/l
Lead sulfate, hydrogen	$Pb(HSO_4)_2 \cdot H_2O$	16.3
Lead sulfite	$PbSO_3$	ins.
Lead thiosulfate	PbS_2O_3	6.1
Lead metatitanate	$PbTiO_3$	ins.
Lead tungstate	$PbWO_4$	6.4
Lithium metaaluminate	$LiAlO_2$	ins.
Lithium metaphosphate	$LiPO_3$	ins.
Lithium metasilicate	Li_2SiO_3	ins.
Lithium orthosilicate	Li_4SiO_3	ins.
Lithium sodium fluoroaluminate	$Li_3Na_3(AlF_6)_2$	0.74 g/l
Lutetium fluoride	LuF_6	ins.
Lutetium oxalate	$Lu(C_2O_4)_3 \cdot 6H_2O$	ins.

(continued)

TABLE A-V-7. (continued)

Compound	Formula	pKsp
Magnesium antimonide	Mg_3Sb_2	ins.
Magnesium metaborate	$Mg(BO_2)_2 \cdot xH_2O$	ins.
Magnesium orthoborate	$Mg_3(BO_3)_2$	ins.
Magnesium carbonate, basic	$3MgCO_3 \cdot Mg(OH)_2 \cdot 3H_2O$	0.4 g/l
Magnesium orthogermanate	Mg_2GeO_4 $(= 2Mg^{++} + GeO_4^{=})$	11.6
Magnesium orthophosphate tetrahydrate	$Mg_3(PO_4)_2 \cdot 4H_2O$	14.0
Magnesium pyrophosphate	$Mg_2P_2O_7$	ins.
Magnesium metasilicate	$MgSiO_3$	ins.
Magnesium orthosilicate	Mg_2SiO_4	ins.
Magnesium tungstate	$MgWO_4$	ins.
Manganese arsenides	$MnAs$ or Mn_2As or Mn_3As	ins.
Manganese pyrophosphate	$Mn_2P_2O_7$	ins.
Manganese phosphides	MnP or Mn_3P_2	ins.
Manganese selenide	$MnSe$	ins.
Manganese (II) metasilicate	$MnSiO_3$	ins.
Mercury (I) azide	$Hg_2(N_3)_2$	14.4
Mercury (II) biphosphate	$HgHPO_4$	13
Mercury (II) bromate	$Hg(BrO_3)_2 \cdot 2H_2O$	3.9-6.9
Mercury (II) oxybromide	$HgBr_2 \cdot 3HgO$	ins.
Mercury (II) oxychloride	$HgCl_2 \cdot 3HgO$	ins.
Mercury (II) oxycyanide	$Hg(CN)_2 \cdot HgO$	ins.
Mercury (II) selenide	$HgSe$	ins.
Mercury (II) sulfate, basic	$HgSO_4 \cdot HgO$	0.03 g/l
Mercury tungstate	Hg_2WO_4 or $HgWO_4$	ins.
Mercury (II) chloride ammonobasic	$Hg(NH_2)Cl$ $(= Hg(NH_2)^+ + Cl^-)$	4.5
Mercury (II) iodide aquobasic ammonobasic	OHg_2NH_2I	ins.
Molybdenum carbides	MoC or Mo_2C	ins.
Molybdenum carbonyl	$Mo(CO)_6$	ins.
Molybdenum hydrotetrachlorodihydroxide	$(Mo_3Cl_4(H_2O)_2)(OH)_2 \cdot 6H_2O$	ins.
Molybdenum metaphosphate	$Mo(PO_3)_6$	ins.
Molybdic acid	$H_2MoO_4 \cdot H_2O$	5.8

(continued)

TABLE A-V-7. (continued)

Compound	Formula	pKsp
Nickel arsenide	$NiAs$	ins.
Nickel orthoarsenite acid	$Ni_3H_6(AsO_3)_4 \cdot H_2O$	ins.
Nickel carbonate, basic	$2NiCO_3 \cdot 3Ni(OH)_2 \cdot 4H_2O$	ins.
Nickel carbonyl	$Ni(CO)_4$	12.5
Nickel chlorate	$Ni(ClO_3)_2 \cdot 6H_2O$	4.1
Nickel phosphides	Ni_2P or Ni_3P_2	ins.
Nickel selenide	$NiSe$	ins.
Nickel subsulfide	Ni_3S_2	ins.
Nickel (II,III) sulfide	Ni_3S_4	ins.
Nickel sulfite	$NiSO_3 \cdot 6H_2O$	ins.
Niobium carbide	NbC	ins.
Niobium nitride	NbN	ins.
Yellow phosphorous	P_4	0.003 g/1
Phosphorous pentasulfide	P_2S_5 (or P_4S_{10})	ins.
Phosphorous sesquisulfide	P_4S_{10}	ins.
Potassium aluminosilicate	$KAl_3Si_3O_{10} \cdot (OH)_2$ or $K_2O \cdot 3Al_2O_3 \cdot 6SiO_2 \cdot 2H_2O$	ins.
Potassium aluminum metasilicate	$KAlSi_2O_6$	ins.
Potassium peroxylammine	$(KSO_3)_2NO$ $(=2KSO_3 + NO)$	4.3
Potassium calcium sulfate	$K_2Ca(SO_4)_2 \cdot H_2O$	2.5 g/1
Potassium chromium chromate, basic	$K_2CrO_4 \cdot 2(Cr(OH) \cdot CrO_4)$	ins.
Potassium cobaltinitrite	$K_3(Co(NO_2)_6)(=3K^+ + Co(NO_2)_6^{-3})$	5.4-9.5
Potassium fluogermanate	K_2GeF_6 $(=2K^+ + GeF_6^=)$	2.4-4.5
Potassium fluosilicate	K_2SiF_6 $(=2K^+ + SiF_6^=)$	0.9-6.2
Potassium fluotitanate	$K_2TiF_6 \cdot xH_2O$ $(=2K^+ + TiF_6^=)$	2.0-4.4
Potassium iodoiridite	K_3IrI_6	ins.
Potassium trimolybdate	$K_2O \cdot 3MoO_3 \cdot 3H_2O$	2.2 g/1
Potassium osmyloxate	$K_2(OsO_2(C_2O_4)_2) \cdot 2H_2O(=2K^+ + (OsO_2(C_2O_4)_2^=)$	3.1-4.9
Potassium tetraoxylate	$KHC_2O_4 \cdot H_2C_2O_4 \cdot 2H_2O$	18 g/1
Potassium sodium nitrocobaltate	$K_2Na(Co(NO_2)_6) \cdot H_2O$	0.7 g/1
Samarium chromate	$SmCrO_4$ or $Sm_2(CrO_4)_3$	14.3
Samarium sulfate, basic	$Sm_2O_2SO_4$	ins.
Selenium carbide	SeC_2	ins.
Selenium nitride	Se_4N_4	ins.
Silieic acids	H_2SiO_5 or H_2SiO_3	ins.
Silicon carbide	SiC	ins.
Silicon hydride	SiH_4	ins.
Silicon nitride	Si_3N_4	ins.

(continued)

TABLE A-V-7. (continued)

Compound	Formula	pKsp
Silver orthoarsenite	Ag_3AsO_3	16.9
Silver azide	AgN_3	ins.
Silver bromate	$AgBrO_3$	4.2
Silver chromate	Ag_2CrO_4	10.3-12.5
Silver dichromate	$Ag_2Cr_2O_7$	10.5
Silver iodomercurate	Ag_2HgI_4	ins.
Silver mercury iodide	Ag_2HgI_4	ins.
Silver metaphosphate	$AgPO_3$	ins.
Silver pyrophosphate	$Ag_4P_2O_7$	ins.
Silver selenate	Ag_2SeO_4	6.8
Silver selenide	Ag_2Se	ins.
Silver thioantimonite	Ag_3SbS_3	ins.
Silver thioarsenite	Ag_3AsS_3	ins.
Silver tungstate	Ag_2WO_4	8.3
Sodium aluminum silicate	$Na_2O \cdot Al_2O_3 \cdot xSiO_2$	ins.
Sodium metaantimonate	$NaSbO_3$	ins.
Sodium antimonate, hydroxy	$NaSb(OH)_4$	0.3-3.0 g/1
Sodium pyroantimonate, dihydro	$Na_2H_2Sb_2O_7 \cdot xH_2O$	ins.
Sodium metabismuthate	$NaBiO_3$	ins.
Sodium hypophosphate	$Na_4P_2O_6 \cdot 10H_2O(=4Na^+ + P_2O_6{}^{-4})$	2.1-4.9
Sodium trititanate	$Na_2Ti_3O_7$	ins.
Sodium metauranate	Na_2UO_4	ins.
Strontinum biphosphate	$SrHPO_4$	28
Strontinum hexaboride	SrB_6	ins.
Strontium molybdate	$SrMoO_4$	6.8
Strontium selenate	$SrSeO_4$	ins.
Strontium metasilicate	$SrSiO_3$	ins.
Strontium sulfite	$SrSO_3$	ins.
Strontium tungstate	$SrWO_4$	4.8
Sulfur	S	ins.
Tetrasulfurdinitride	S_4N_2	ins.
Trisulfurdinitrogen dioxide	$S_3N_2O_2$	ins.
Tantalum carbide	TaC	ins.
Tantalum nitride	TaN	ins.
Tellurium diiodide	TeI_2	ins.
Tellurium oxides	TeO_2 or TeO or TeO_3	ins.
Tellurium sulfide	TeS	ins.
Tellurous acid	H_2TeO_3	12.7
Tellurium	Te	ins.
Terbium peroxide	Tb_4O_7	ins.

TABLE A-V-7. (continued)

Compound	Formula	pKsp
Thallium azide	$TlN_3 (=Tl^{++} + N_3^{=})$	3.8-4.3
Thallium chromate	Tl_2CrO_4	3.7-9.1
Thallium dichromate	$Tl_2Cr_2O_7$	ins.
Thallium molybdate	Tl_2MoO_4	ins.
Thallium selenide	Tl_2Se	ins.
Thallium pyrovanadate	$Tl_4V_2O_7 (=4Tl^{+} + V_2O_7^{-4})$	10.6-11.2
Thorium borides	ThB	ins.
Thorium oxysulfide	$ThOS$	ins.
Thorium hypophosphate	$ThP_2O_6 \cdot 11H_2O$	ins.
Thorium selenate	$Th(SeO_4)_2 \cdot 9H_2O$	4.0-5.8
Thorium pyrovanadate	$ThV_2O_7 \cdot 6H_2O$	ins.
Thulium	Tm	ins.
Thulium fluoride	TmF	ins.
Thulium oxalate	$Tm_2(C_2O_4)_3 \cdot 6H_2O$	ins.
Tin biphosphate	$SnHPO_4$	ins.
Tin pyroarsenate	$Sn_2As_2O_7$	ins.
Tin phosphides	SnP, SnP_3	ins.
Tin selenide	$SnSe$	ins.
Tin tellurides	$SnTe$, $SnTe_2$	ins.
Titanium carbide	TiC	ins.
Titanium nitride	TiN	ins.
Titanium phosphide	TiP	ins.
Tungsten arsenide	WAs_2	ins.
Tungsten diboride	WB_2	ins.
Tungsten carbides	WC and W_2C	ins.
Tungsten carbonyl	$W(CO)_6$	ins.
Tungsten phosphides	WP and WP_2	ins.
Uranium hydride	UH_3	ins.
Uranyl phosphate, mono-H	$UO_2HPO_4 \cdot 4H_2O$	ins.
Vanadic acid meta or tetra	HVO_3 or $H_2V_4O_{11}$	ins.
Vanadium carbide	VC	ins.
Vanadium nitride	VN	ins.
Vanadium oxychloride	$VOCl$	ins.

(continued)

TABLE A-V-7. (continued)

Compound	Formula	pKsp
Ytterbium (III) selenide	$Yb_2(SeO_3)_3$	ins.
Yttrium hexamntipyrine perchlorate	$(Y(C_{11}H_{12}N_2O)_6)(ClO_4)_3$	8.3
Zinc aluminate	$ZnAl_2O_4$	ins.
Zinc arsenide	Zn_3As_2	ins.
Zinc chromate	$ZnCrO_4$	ins.
Zinc gallate	$ZnGa_2O_4$	ins.
Zinc pyrophosphate	$Zn_2P_2O_7$	ins.
Zinc silicate	$ZnSiO_3$	21.0
Zinc selenide	$ZnSe$	ins.
Zinc sulfite	$ZnSO_3 \cdot 2H_2O$	4.1
Zinc tellurate	Zn_3TeO_4	ins.
Zirconium biphosphate	$Zr_2(HPO_4)_3$	18
Zirconium carbide	ZrC	ins.
Zirconium carbonate, basic	$3ZrO_2 \cdot CO_2 \cdot H_2O$	ins.
Zirconium nitride	ZrN	ins.
Zirconium phosphide	ZrP_2	ins.
Zirconium selenite	$Zr(SeO_3)_2$	ins.
Zirconium orthosilicate	$ZrSiO_4$	ins.
Zirconium sulfide	$ZrOS$	ins.

TABLE A-V-8. SOLUBILITY OF "INSOLUBLE" HALIDES (5,6,7,8,9,10)

Cation	Cl^-	Br^-	I^-
Copper	6.4 - 7.0 (I)[a]	8.0 - 8.3 (I)	8.8 - 12.0 (I)
Lead	2.2 - 3.7 (II) dec. (IV)	2.1 - 5.1 (II) 5.2 (IV)	5.6 - 8.5 (II) 8.0 (IV)
Mercury	17.5 - 20.3 (I) -1.2 - 1.3 (II)	22 - 27 (I) 2.3 - 4.7 (II)	28 (I) 10.4 (II)
Molybdenum	ins. (II,III)	ins. (II,III)	ins. (II) ? (III)
Silver	7.7 - 10.4 (I)	9.4 - 12.4	13.8 - 18.3 (I)
Thallium	2.0 - 3.8 (I)	4.1 - 5.7 (I)	4.9 - 9.5 (I)
Strontium (II)	-1.34 to -1.75	-2.4 to -3.5	3.6 to 8.5

[a] Oxidation state.

TABLE A-V-9. SOLUBILITY OF INORGANIC SUBSTANCES WITH WELL-STUDIED ANIONS (5,6,7,8,9,10)[a]

Name	Possible Oxidation States	Florides (F^-)	Carbonates ($CO_3^=$)	Hydroxides (OH^-)	Sulfates ($SO_4^=$)	Sulfides ($S^=$)
Aluminum	III	3.3		32 to 33	-1.8 to -8.1	dec.
Antimony	III,V	dec.(III),sol.(V)		41 (III)	ins. (III,V)	ins. (V), 19.5 to 93(III)
Arsenic	III,V	dec.(III,V)				26.4(III);33.4(V)
Barium	II	4.1 to 6.0	7.0 to 8.3	-2 to 1.7	9.5 to 10.0	dec.(II); 97(III);-3.2(IV)
Beryllium	II	sol.		20	sol.(II)	
Bismuth	III,V	dec.(III); ins.(V)		20 to 30 (III)	dec.(III)	30 to 91 (III)
Boron	III	-6.2 to -8.1				dec.(III,V)
Cadmium	II	1.0 to 1.1	8.7 to 14	13 to 14 (II)	-0.33 to -1.12	4.1 to 28
Calcium	II	10.4 to 10.5	7.4 to 8.3	4.2 to 5.3	3.4 to 5.0	4.4 to 5.1
Cerium	III,IV	?[b] (III,IV)	ins.(III)	20.2 (III)	1.7 to 9.2(III); dec.(II)	ins. (III)
Chromium	II,III,VI	ins.(III);sol.(II), dec. (IV)		19(II);30(III)	0.7(II); -3.2(III)	
Cobalt	II,III	-1.2(II);dec., sol. (III)	ins.(II)	12.8 to 15.7(II); 22.2 (III)	-1.5 to 24.7(II); sol. (III)	9 to 27
Copper	I,II	0.4 to 6.8 (II); ins.(I)	10.0	19.2 to 19.6(II)	-1.8 to 0.1(II); dec.(I)	10.9(II);45 to 48 (I)
Dysprosium	III	ins.	ins.		3.8 to 4.7	
Europium	II,III	ins. (II,III)			ins.(II);5.3 to 5.9	
Gallium	I,II,III	13.8(II)		ins.	sol.	dec.(I,III);ins. (II)
Hafnium	IV					
Holmium	III					
Indium	III	0.3 to 9.1(III)		ins.(III)	sol.(III)	ins.(III)
Iron	II,III	sol.(II,III)	6.5 to 10.7(II)	14 to 15 (II); 38.8(III)	17.2(II);-6.5(III)	22
Lanthanum	III		ins.	ins.	4.3 to 7.6 (III)	
Lead	II,IV	7.1 to 7.4 (II); 7.5 (IV)	10.8 to 13.3(II)	9 to 16 (II)	5.7 to 7.8 (II)	10.9 to 28.1 (II)
Lutetium	III	ins.	ins.		-0.7 to 1.3	
Magnesium	II	5.7 to 8.2	5.0 to 5.8(II)	8.9 to 11.2	-1.0 to -0.7	dec.

[a] dec. = decomposes; ins. = insoluble, sol. = soluble (exact data not available)

[b] Cerium (III and IV) floride is reported by different authors to be soluble, insoluble or to decompose in aqueous solutions.

(continued)

TABLE A-V-9. (continued)

Name	Possible Oxidation States	Florides (F^-)	Carbonates ($CO_3^=$)	Hydroxides (OH^-)	Sulfates ($SO_4^=$)	Sulfides ($S^=$)
Manganese	II to VII	2.8 to 3.3(II); dec. (III)	6.5 to 10.7(II)	12.8 to 14.0(II); ins.(III)	-2.6 to -1.1(II)	8.5 to 22(II); ins.(IV)
Mercury	I,II	dec.(I,II)	20.4(I)	23(I); 25(II)	dec.(II);4.6 to 8.2(I)	52 to 54(II); ins.(I)
Molybdenum	III,IV,VI	dec.(VI)		6.0(III)		ins.(IV,V,VI); sol.(III)
Nickel	II,III	0.5 to 0.8(II)	6.2 to 9.0(II)	8.0 to 18.0(II)	-0.6 to -2.5(II)	8.8 to 27(II)
Niobium	III,V	dec.(V)				
Radium	II		ins.		13.6 to 14.4(II)	
Ruthenium	III to VI,VIII	dec.(V)		sol.		ins.(IV)
Samarium	II,III	ins.(III)		ins.(III)	4.1 to 5.8(III)	
Scandium	III			ins.(III)	<0.8	
Selenium	II,IV,VI	dec.(IV,VI)				ins.(II,IV)
Silicon	I to IV	dec.(III,IV)				dec.(I,II,IV)
Silver	I,II	-2 to 16(I); dec.(II)	5.5 to 11.2(I)	7.7(I)	4.8 to 4.9(II); 4.6 to 6.4(I)	46 to 49(I)
Strontium	II	8.6	4.7 to 9.9	-1.4 to 3.8	6.2 to 6.4(II)	sol.
Tantalum	V	sol.				ins.
Terbium	III	ins.			4.6 to 5.3	
Thallium	I,II,III	-1.1(I);dec.(III)	-0.1 to 2.6	-0.1 to 1.0(I);43(III)	0.7 to 2.5	9 to 23(I);ins.(III)
Thorium	IV	14.3	ins.	ins.	1.4 to 4.1	ins.
Thulium	III	ins.				
Tin	II,IV	sol.(II,IV)		25(II)	-0.4(II); sol.(IV)	14.3(IV); 14 to 25(II)
Titanium	III,IV	sol.; dec.(IV)			ins.(III)	ins.(II,III);dec.(IV)
Tungsten	VI	dec.				sol.(VI);ins.(IV)
Uranium	II to VI	ins.(IV);dec.(III,VI)			-0.7 to 1.5(IV)	dec.(IV)
Vanadium	III to V	ins.(III);sol.(IV,V)		15(II);34(III);23(V)	sol.(III)	ins.(III,V)
Ytterbium	II,III	ins.(II,III)		-1.2 to 3.6 (III)		
Yttrium	III	ins.	ins.	ins.	4.8-6.9	
Zinc	II	1.8 to 8.6	8.2	16.7 to 17.0	-2.7 to 24	8.3 to 22.8
Zirconium	IV	2.2 to 3.0		12 to 52(IV)	-0.34	ins.

(continued)

TABLE A-V-9. (continued)

NAME	Phospnates (PO_4^{-3})	Arsenates (AsO_4)	Element	Oxide ($O^=$)	Oxylate ($C_2O_4^=$)	Iodate ($IO_3^=$)	Silicide $Si^=$
Aluminum	18.2	ins.	ins.	23.1	ins.		
Antimony		16	ins.	13.9(III); 20.9(V) sol. (IV)			
Arsenic		18	ins.	-9.8 to -7.8 (III); -1.0 to -1.6 (V)			
Barium	ins.	6 to 50	dec.	-1.5 to 1.3	6.0 to 7.8	-2.4 to 10.8	dec.
Beryllium	38(II)	20	ins.	10.2	-0.81		
Bismuth	22.9(III)	9.4(III);29(V)	ins.	ins. (III to V)	dec.	ins.	ins.
Boron		2.1(III)	sol.	-3.8 to 2.0(III); dec.(II)			
Cadmium	32.	32.7	ins.	ins.	6.9 - 7.8	sol.	
Calcium	18.4 to 19.9(cold);dec.(hot)	15.4 to 18.2	dec.	dec.	7.9 - 8.9	4.2 - 7.2	ins.
Cerium	ins.		dec.	ins.	sol.	16.3(IV);9.1(III)	ins.
Chromium	22.6 (III)		ins.	-4.7 to ins.	sol. (II, III)	3.0 to 3.9	ins.
Cobalt	ins. (II)	ins.	ins.	ins. (III, IV)	ins. (II)	5.3(II)	
Copper	35.1 (II)	ins.	ins.	ins. (I, II)	7.6 to 7.7(II)	5.7 to 7.3(II)	
Dysprosium	ins.		ins.		ins.		
Europium			ins.				
Gallium			ins.	ins. (I)	8.3		
Hafnium			ins.	ins.			
Indium			ins.	ins. (II, III)		10.5(III)	
Iron	ins.(II);2.9(III)	20.2(III)	ins.	ins.(II,IV);sol(III)	Very sol. (III); 5.7 to 5.8 (II)	sol.	ins.

(continued)

TABLE A-V-9. (continued)

Lanthanum			dec.	ins.(II); 22.5(III)	27.7	4.9 (III)	
Lead	32-42 (II)	35.4(II)	ins.	8.0-8.2(II); ins. (III)	10.5 to 11.1 (II)	12.2 to 13.4(II)	
Lutetium					ins.		
Magnesium	ins.	19.7	dec.	5.3 - 7.6	4.1 to 4.7	0.5 to 1.3	dec.
Manganese	ins.	28.7(II)	dec.	ins.(III,IV,II);sol(VII)	5.4 to 15.0		ins.(II to VII)
Mercury		sol.	ins.	ins.(I); 3.5 to 7.2 (II)	ins.(I);6.9(II)	ins.(II);13.7(I)	
Molybdenum			ins.	ins.(IV); sol.(V); 2.0 to 7.1(III)			
Nickel	30(II)	ins. (III)	ins.	ins.(II)	ins.(II)	4.0 to 4.3(II)	ins.
Niobium			ins.	dec. (IV), ins. (II,V)			
Radium			dec.			9.9	
Ruthenium			ins.	ins. (IV), sol. (VIII)			ins.(IV)
Samarium			ins.	ins. (III)	28.7 (III)		
Scandium				ins.	dec.		
Selenium			dec.	-3.2 to 1.0(IV); sol.(VI)			
Silicon			ins.	ins. (II,IV); 7.9 (I)			
Silver	17.8 to 20(II)	17.5 to 22(I)	ins.	10.3 to 12.2 (I)	11.3	6.3 to 7.9(II); 7.5(I)	
Strontium	27 to 31 (II)	18 (II)	dec.	-0.7 to 2.4	1.2 to 9.2	4.6 to 8.9	
Tantalum			ins.	ins. (IV,V)			
Terbium			ins.		ins.		
Thallium	6.7 to 7.2 (I)		ins.	dec. (I); ins. (III)	1.6 to 4.0	5.5 to 5.6	
Thorium	ins.		1.6 to 1.9	ins.	12.5	ins.	

(continued)

TABLE A-V-9. (continued)

Thulium			ins.		ins.		
Tin	ins.(II)		ins.	ins.(II,IV)			
Titanium			ins.	ins.(III,IV)	sol.(III)		
Tungsten			ins.	ins.(IV to VI)		ins.	
Uranium			ins., dec.	ins.(IV,VI)			
Vanadium	24(V)		ins.	ins.(II. VI); 5.4(V); sol.(III)		ins.	
Ytterbium			ins.	ins.(III)	24.9(III)		
Yttium			dec.	23.5(III)	26.9		
Zinc	32.0(II)	27.9(II)	ins.	9.4	8.8	ins.	
Zirconium			ins.	8(IV)	3.0 to 4.5	ins.	

For example, elemental mercury is considered to be quite "insoluble"; however, microbial methylation in sediments can change the form of mercury to a compound which is quite soluble and easily adsorbed by aquatic biota. This mercury is then in a form which can be easily absorbed by predators of the aquatic biota, including fish-eating birds and humans.

The pK_{sp} is a measure of the solubility of a compound in moles per liter -- the higher the pK_{sp}, the more insoluble the compound. However, if two compounds have the same molecular weight and solubility in grams per liter, the mathematical calculations will show the compound which dissociates into the most ions to have a higher pK_{sp}.

In some cases, the dissociation which is more likely to occur is not obvious. In some of these cases a dissociation was assumed and is shown in Tables A-V-7 and A-V-9. In other cases the solubility was given in grams per liter rather than pK_{sp}. In all other cases where the solubility is given in pK_{sp} and no dissociation is shown, the compound is assumed to be completely dissociated.

Exact quantification of the solubility of many inorganic compounds is not possible if these compounds are reported as "practically insoluble," "very slightly soluble," etc. Examination of the literature for a few compounds for which such comparisons can be made has shown that compounds which are reported as "practically insoluble" by one author may have been found by another author to have pK_{sp}'s ranging from 5.7 to 54. "Insoluble" compounds have pK_{sp}'s ranging from 10 to 54. "Slightly soluble" compounds have pK_{sp}'s ranging from 4.2 to 28.7. One compound reported as "very slightly soluble" by one author was found to have a pK_{sp} of 15.7 by another author, while an "almost insoluble" compound had a pK_{sp} of 7.2. "Sparingly soluble" compounds have pK_{sp}'s ranging from 7 to 23, while a "very sparingly soluble" compound was found to have a pK_{sp} of 5.7 and an "extremely insoluble" compound was found to have a pK_{sp} of 10. Incidentally, the pK_{sp}'s of "soluble" compounds range from approximately -10 to 24.

Unfortunately, specific information on the solubility of most compounds is not available. This makes practically impossible the determination of the form in which the element is likely to be found. For example, both cobalt (II) phosphate and barium phosphate are "insoluble." From this information, it is not possible to determine which of these compounds will precipitate from an equimolar solution of barium chloride and cobalt (II) phosphate. All that is known for certain, given this information, is that a precipitate will form in which the anion is the phosphate and the cation is either barium, cobalt, or an undefinable mixture of the two.

For the remainder of this discussion, "insoluble" will be defined as any compound which has a pK_{sp} greater than 4 or is listed as "insoluble" in the literature. The term "soluble" refers to any compound which has a pK_{sp} of 4 or less or is listed in the literature as "soluble." Those compounds which have adverbs associated with this designation (i.e., "very slightly soluble") are considered as soluble. Solubility information on any compound described in the literature as "insoluble" with an associated adverb (such as "practically insoluble"), is considered to be too vague for categorization. When the pK_{sp}'s are available or can be calculated from information contained in the literature, they will be dealt with preferentially.

Tables A-V-8 and A-V-9 are companion tables. All chlorides of the elements listed in Table A-V-9 decompose or are soluble with pK_{sp}'s ranging from less than -7.5 to 1.8, with the exception of copper (I) chloride (cuprous chloride), lead (II) chloride (cotunite), mercury (I) chloride (mercurous chloride), silver (I) chloride (cerargyrite), and thallium (I) chloride. The chlorides of the other oxidation states of these metals are soluble or decompose. Except as noted the bromides are soluble with pK_{sp}'s ranging from -1.6 to -5.0. The pK_{sp}'s for the iodides not listed in Table A-V-8 range from 2.3 to 4.1 (both for tin (II) iodide) to -5.5. All compounds found in the indicated references of Table A-V-9 of potassium, rubidium, lithium (except lithium phosphate, $pK_{sp} = 8.5$), ammonia, sodium, cesium, germanium, and iodine of the anions listed in Table A-V-9 either are soluble or decompose in aqueous media. All nitrates and nitrites of the elements listed in Tables A-V-8 and A-V-9 are soluble in water. Table A-V-7 lists insoluble inorganic compounds in which only a few elements are known to give insoluble compounds with the particular anionic species.

The values of the pK_{sp} shown in Tables A-V-7, A-V-8, and A-V-9 are ranges of numbers expressed to two significant figures. This results in part from the difficulty in determination of the exact solubilities of some of the more insoluble compounds. A compound of two ions with a pK_{sp} of 48 has an average of less than one molecule dissolved in a liter of water at any particular instant.

The molecular formula assumed for the compound also affects the pK_{sp}. For example, gold (III) chloride dissolves at a rate of 680 grams per liter. Calculation of the pK_{sp} using the formula $AuCl_3$ gives a pK_{sp} of -2.83 while calculation of the pK_{sp} using the formula Au_2Cl_6 gives a pK_{sp} of -5.67.

The degree of hydration also affects the pK_{sp}. Indium fluoride, InF_3, has a pK_{sp} of 9.1. Indium fluoride trihydrate, $InF_3 \cdot 3H_2O$ has a pK_{sp} of 0.3, while indium fluoride nonahydrate, $InF_3 \cdot 9H_2O$ is listed as "slightly soluble." In calculation of the ranges of pK_{sp}'s found in Tables A-V-7, A-V-8, and A-V-9, the hydrated forms were included.

The crystalline form of the compound also affects the solubility. Zinc sulfide (alpha), ZnS, (natural wurtzite), has a solubility of 0.0069 g/l at 18°C (pK_{sp} = 8.3); zinc sulfide (beta), ZnS, (Natural sphalerite) has a solubility of 0.00065 g/l (pK_{sp} = 10.4) while zinc sulfide monohydrate, $ZnS \cdot H_2O$ is "insoluble" (4). Other authors report a pK_{sp} for this compound of 24.

The decomposition products of the element or inorganic compound must be considered in evaluation of the possible effect of the element in the environment. Unfortunately, the decomposition products often are not specified and may not be known. In general, elements of the first two groups of the periodic table decompose on exposure to water to their corresponding base with the evolution of hydrogen:

$$Ba + 4H_2O = 2Ba(OH)_2 + 2H_2 \text{ (gas)}.$$

Arsenic tribromide forms arsenic trioxide and hydrogen bromide when in contact with water. Arsenic trichloride forms arsenic trihydroxide and hydrogen chloride. Bismuth tribromide forms bismuth oxybromide and bismuth trichloride forms bismuth oxychloride. The compounds of phosphorus in general decompose to phosphoric or phosphorous acid on contact with water. Silicon tetrachloride gives silicic acid and hydrogen chloride. Boron hydroxide gives H_3BO_3 and hydrogen (4). Generally, hydrides decompose in aqueous media except as noted. In general, these are redox reactions and such reactions are observed with the other elements.

The melting points, boiling points, and solubilities of selected inorganic compounds are presented in Table A-V-10. In order to be included in this table, a particular inorganic compound had to have a boiling point less than 100°C and not decompose when contacting water.

The abiotic and biotic factors influencing the environmental transport of trace elements in soils are discussed in Table A-V-11. The appropriate references are found in the footnotes to this table.

A-V.2 SAM/IA Analysis of Projected SRC Facility as Discussed in This Report (11)

Figure A-V-8 and Tables A-V-12 and A-V-13 are the SAM/IA analysis for the SRC facility described in this report. Table A-V-11 is an example of a SAM/IA worksheet for Level 2. A similar worksheet was prepared for each waste stream as listed in Table A-V-11. In many cases estimates of the quantity of a particular waste stream could not be done. Thus, complete SAM/IA analysis of our hypothetical facility could not be carried out. The values determined from these worksheets have been transcribed onto Table A-V-12. Table A-V-13 demonstrates some of the problems of a SAM/IA analysis. The pollutant species listed first on the worksheet (Alkalinity through pH) are so general that: (1) the MATEs are not available and (2) specific environmental impacts cannot be predicted anyway. Of the more than 250 materials for which MATEs are available, the analyses of only six are available for coal pile drainage. The MATEs are unavailable for four of the 10 specific substances analyzed in the coal pile drainage. No information

TABLE A-V-10. MELTING POINTS, BOILING POINTS, AND SOLUBILITIES OF SELECTED INORGANIC COMPOUNDS

Name	Formula	M.P.	B.P.	Solubility (g/l)[a]		
				Cold Water	Hot Water	Organic Solvents
Ammonia	NH_3	-77	-33	899	74^{100}	sol.
Ammonia carbonate	$NH_4CO_2NH_2$		58^b	v. sol.	dec.	ins.
Ammonia hydrogen sulfide	NH_4HS		33	1,281	dec.	sol.
Ammonia cyanide	NH_4CN	36	*ca.* 36	v. sol.	dec.	v. sol.
Antimony hydride	SbH_3	-88	-17	4.1^{0}		
Arsenic pentafluoride	AsF_5	-8	-53	sol.		
Arsenic hydride (Arsine)	AsH_3	*ca.*-116	*ca.*-60	sol.		sol.
Beryllium borohydride	BeB_2H_8		90^b			
Borinoaminoborine	B_2H_7N	-66	76			
Diboronbromide, mono-pentahydride	B_2H_5Br	-104	*ca.* 10			
Borine carbonyl	BH_3CO		-64			
Boron trifluoride	BF_3	-127	*ca.*-105	1060	dec.	
Boron hydride	B_2H_6	-166	-92			
Diborane hydrobromide	B_2BrH_6	-104	16			
Boron hydride	B_4H_{10}	-120	16	sl. sol.		sol.
Tetrahydropentaborane	B_5H_{11}		67			
Triborine triamine	$B_3H_6N_3$	-58	51			
Bromine	Br_2	-7	59	35.8^{20}	35.2^{50}	sol.
Carbon tetrachloride	CCl_4	-23	77		ins.	sol.
Carbon tetrafluoride	CF_4	-184	128	sl. sol.		
Carbon dioxide	CO_2		-78^b	3.48^{0}	0.97^{40}	sol.
Carbon monoxide	CO	-199	-192			sol.
Carbon oxysulfide	COS	-139	-50			sol.
Carbon selenide, sulfide	CSeS	-85	84	ins.	ins.	sl. sol.
Carbon disulfide	CS_2	111	46	2.2^{22}	1.4^{50}	sol.
Carbonyl bromide	$COBr_2$		64			
Chlorotrifluoromethane	$CClF_3$		-81			
Cyanogen	C_2N_2	*ca.*-30	-21	10^{20}		sol.
Cyanogen bromide	CBrN	58.	62.			
Cyanogen chloride	CClN	-6.	13			
Cyanogen fluoride	CFN		73^b			
Dichlorodifluoromethane	CCl_2F_2		-30			
Dichlorofluoromethane	$CHCl_2F$	-135	9			
Chlorodifluoromethane	$CHClF_2$	-160	-41			
Trichlorofluoromethane	CCl_3F		24.			

(continued)

TABLE A-V-10. (continued)

Name	Formula	M.P.	B.P.	Solubility (g/1)[a]		
				Cold Water	Hot Water	Organic Solvents
Chlorine	Cl_2	-103	-34	14.6^{0}	5.7^{30}	sol.
Chlorine dioxide	ClO_2	- 60	10	62	dec.	
Chlorine monoxide	Cl_2O		4	0.8	dec.	
Chlorotetroxyfluoride	ClO_4F	-167	-16			
Chlorylperfluoride	ClO_3F	-146	-47			
Cobalt nitrosyl carbonyl	$Co(NO)(CO)_3$	- 1	49	ins.		sol.
Cobalt nitrosyl tricarbonyl	$Co(CO)_2NO$	- 11	80			
Fluorine	F_2	-223	-118		dec.	
Fluorine monoxide	F_2O	-224	-145	sl. sol.	ins.	
Fluorine dioxide	F_2O_2	-164	- 57			
Germanium tetrahydride	GeH_4	-165	- 88	ins.	ins.	
Tetramethylgermanium	$Ge(CH_4)_4$	- 88	44			
Hydroazoic acid	HN_3	- 80	37	sol.	sol.	sol.
Hydrogen	H_2	-259	-253	1.5×10^{-5}	6.0×10^{-6}	ins.
Bismuthide	H_3Bi		22			
Hydrogen bromide	HBr	- 88	- 67	2210^{0}	1300^{100}	sol.
Hydrogen chloride	HCl	-115	- 85	823^{0}	561^{60}	sol.
Hydrogen cyanide	HCN	- 14	26	sol.	sol.	sol.
Hydrogen fluoride	HF	- 83	20	sol.	sol.	
Hydrogen iodide	HI	- 51	- 35	2	sol.	sol.
Hydrogen phosphide	H_3P	-134	- 87	0.4	ins.	sol.
Hydrogen phosphide	H_4P_2	- 90	58	ins.	ins.	sol.
Hydrogen sulfide	H_2S	- 86	- 61	4370^{0}	1860^{40}	sol.
Hydrogen selenide	H_2Se	- 64	- 41			
Hydroxyl amine	NH_2OH	33	56	sol.	dec.	sol.
Hydroxyl amine acetate	$NH_2OH \cdot CH_3CO_2$	87	90[b]	sol.		
Nickel carbonyl	$Ni(CO)_4$	- 25	43	0.18		sol.
Nitric acid	HNO_3	- 42	83	v. sol.	v. sol.	sol.
Nitrogen trichloride	NCl_3	<- 40	< 71	ins.	dec.	sol.
Nitrogen trifluoride	NF_3	*ca.*-200	-129	sl. sol.		
Nitrogen oxide	NO	*ca.*-164	-152	9.8×10^{-4}	3.2×10^{-4}	sol.
Nitrogen oxide	N_2O	- 91	- 88	2.6	1.1	sol.
Nitrogen pentoxide	N_2O_5	30	*ca.* 32	sol.	dec.	sol.
Nitrosyl fluoride	NOF	-134	- 56			
Nitrogen tetroxide	N_2O_4	- 9	21			
Ozone	O_3	-192	-112			

(continued)

TABLE A-V-10. (continued)

Name	Formula	M.P.	B.P.	Solubility (g/l)[a] Cold Water	 Hot Water	 Organic Solvents
Phosphorus trihydride (Phosphine)	PH_3	-133	- 88	200		
Rhenium oxytetrafluoride	$ReOF_4$	40	63			
Selenium hydride	H_2Se	60	- 41	37.7^{4}	$2700^{22.5}$	
Bromosilane	SiH_3Br	- 94	2			
Chlorosilane	SiH_3Cl	-118	- 30			
Bromodichlorofluorosilane	$SiBrCl_2F$	-112	35			
Bromotrifluorosilane	$SiBrF_3$	- 70	- 42			
Difluorosilane	SiH_2F_2		- 78			
Dibromochlorofluorosilane	$SiBr_2ClF$	- 99	60			
Dibromodifluorosilane	$SiBr_2F_2$	- 67	14			
Disilane	Si_2H_6	-133	- 14			
Disiloxane	$(SiH_3)_2O$	-144	- 15			
Fluorotrichlorosilane	$SiCl_3F$	-121	12			
Hexafluorodisilane	Si_2F_6	- 19	- 19[b]			
Tetrasilane	Si_4H_{10}	- 94	100			
Tribromofluorosilane	$SiBr_3F$	- 83	84			
Trisilane	Si_3H_8	-117	53			
Disilazane	$(SiH_3)_3N$	-106	49			
Silicon hydride	SiH_4	-185	-112	ins.		
Silicyl oxide	$(SiH_3)_2O$	-144	- 15	v. sl. s.	sl. d.	
Silicon tetrachloride	$SiCl_4$	- 69	57			
Silicon tetrafluoride	SiF_4	- 90	- 95[b]			
Sulfur hexafluoride	SF_6	- 51	64	sl. s.	sl. s.	
Sulfur dioxide	SO_2	- 73	- 10	$228.^{0}$	5.8^{90}	
Thionyl chloride	$SOCl_2$	-104	75			
Tellurium hydride	H_2Te	- 49	- 2	sol.	sol.	
Tin hydride	SnH_4	-150	- 52			

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[a] v. sol. = very soluble
sol. = soluble
dec. = decomposes
ins. = insoluble
sl. sol. = slightly soluble
superscripts show temperature in degrees centigrade

[b] Sublimes

(continued)

TABLE A-V-10. (continued)

	MATE		AMBIENT LEVEL GOAL	
Element	Based on Health Effects	Based on Ecological Effects	Based on Health Effects	Based on Ecological Effects
Tantalum and compounds	>675.[c]		>1.6[c]	
Tellurium and compounds	1,500.		1.4	
Thallium and compounds	1,500.[b]		1.4[b]	
Thorium and compounds	>675.[c]		>1.6[c]	
Tin and compounds[a]				
Organotin compounds	1,500.		1.4	
Tin hydride (SnH_4)[d]	>0.[c]		>0.[c]	
Titanium and compounds	90,000.[b]	820.	83.	4,100.
Tungsten and compounds	15,000.		14.	
Uranium and compounds	60,000.[b]	500.	3.	100.
Vanadium and compounds	2,500.[b]	150.	7.	75.
Ytterbium and compounds	>675.[c]		>1.6[c]	
Yttrium and compounds	>675.[c]		>1.6[c]	
Zinc and compounds	25,000.[b]	100.	5,000.[b]	20.
Zirconium and compounds	>67.5[c]		>0.16[c]	

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[a] Except as noted below.

[b] These MEC values may be "unreasonable." They are dealt with on an individual basis in the text.

[c] Estimated from the information contained in Table VI-2.

[d] This compound (or element) is very toxic and should not be tolerated. Also included in this group are the rarer radioactive elements including radium and radon.

TABLE A-V-11. ABIOTIC AND BIOTIC FACTORS INFLUENCING THE ENVIRONMENTAL TRANSPORT OF TRACE ELEMENTS IN SOIL

Element	Microbes Capable of Changing Chemical Form	Bound by Soil Organic Matter	Solubilized by Acid Production or Chelation	Poor Soil Drainage Increases Availability	Reference*
Aluminum			+		A,B
Arsenic	+		+		A,B,C
Barium				+	D
Beryllium		+			D
Boron		- (b)		+	A,B,D
Bromine		+			A,B
Cadmium		+	+		A,C
Calcium		+ (a)			A,B
Chromium	+			+	A,B,E
Cobalt			+	+	A,B,D
Copper		+	+		A,B,F,G,H
Gallium				+ (?)	D
Germanium		+			A,B
Iodine	+	+			A,B
Iron	+	+	+		A,B,H
Lead		+	+		A,B,C,I
Magnesium		+ (a)			A,B
Manganese	+	+ (a)	+	+	A,B,E,H
Mercury	+		+		A,B,C
Molybdenum	+	+		+	A,B,E,H
Nickel			+	+	A,B,E
Nitrogen	+	- (c)			A,B
Phosphorous		+	+		A,B
Plutonium	+				J
Selenium	+	+		-	A,B
Sulfur	+	- (d)			A,B
Tellurium	+				A,B
Thallium			+		A,B,D
Tin		+		+	A,B,D
Uranium	+	+			B
Vanadium	+			+	A,B,H
Zinc		+ (a)	+		A,B,H
Zirconium		+			D

(a) Relatively easy to leach from soil organic matter.
(b) As borate
(c) As nitrate.
(d) As sulfate

(continued)

TABLE A-V-11. (continued)

*Reference A: Weir, E.E., L. Parker, H. Hopkins, K. McKeon, H.E. Lipsitz, C.R. Thompson, J. Robbins, D. Dow, V. DiPasquale, and B. May. Chapter IX. Environmental Effects after Treatment. In: Environmental Assessment of Effluents from Coal Liquefaction, Hittman Associates, ed. Contract No. 68-02-2162/Task Directive 4, U.S. Environmental Protection Agency, Industrial and Environmental Research Laboratory, Research Triangle Park, North Carolina, 1977.

Reference B: Bowen, H.J.M. Trace Elements in Biochemistry. New York: Academic Press, 1966.

Reference C: Gehrs, C.W. A Conceptual Approach to Evaluating Liquid Effluents from Synthetic Fuel Processes. Preprint: Proc. of Symposium on Management of Residuals from Synthetic Fuels Production. Denver Research Institute, May 23-27, 1976.

Reference D: Lisk, D.J. Trace Metals in Soils, Plants, and Animals. In: Advances in Agronomy, Vol. 24, N.C. Brady ed. Academic Press, New York, 1972. pp. 267-325.

Reference E: Dvorak, A.J., C.D. Brown, E.H. Dettman, R.A. Hinchman, J.D. Jastrow, F.C. Kornegay, C.R. LaFrance, B.G. Lewis, R.T. Lindy, R.D. Olsen, J.I. Parker, E.D. Pentecost, J.L. Saquinsin and W.S. Vinkor. The Environmental Effects of Using Coal for Generating Electricity. NUREG-0252 (PB 267-237), 1977.

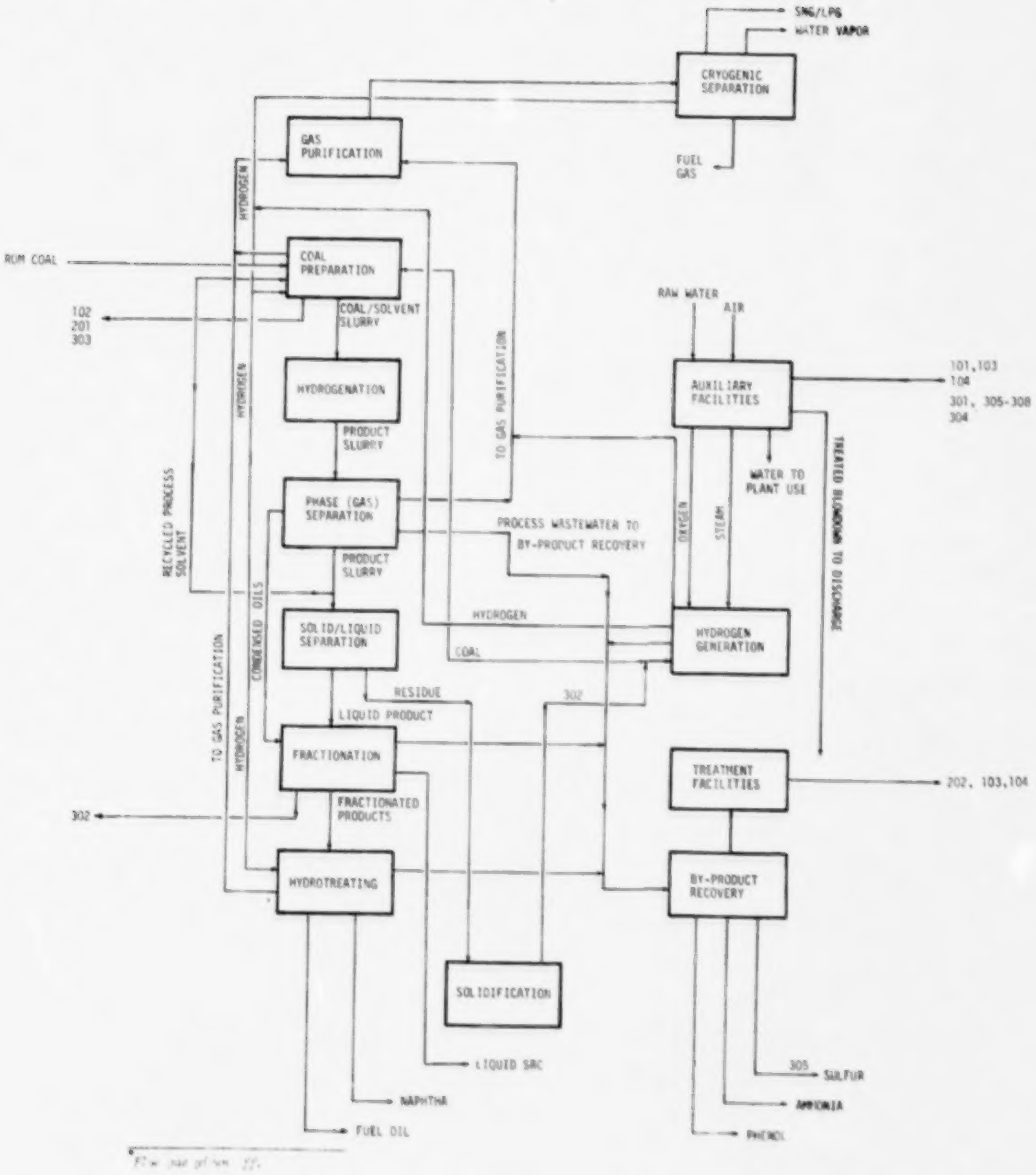
Reference F: National Academy of Sciences. Copper. National Academy of Sciences, Washington, D.C., 1974.

Reference G: European Inland Fisheries Advisory Commission Working Party on Water Quality Criteria for European Freshwater Fish. Report on Copper and Freshwater Fish. Food and Agriculture Organization of the United Nations, Rome, 1976, 16 pp.

Reference H: Ross, R.H. Environmental Interactions. In: Environmental, Health, and Control Aspects of Coal Conversions: An Information Overview. Vol. 2., H.M. Braunstein, E.D. Copenhaver, and H.A. Pfuder, eds. Information Center Complex, Information Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee, 1977.

Reference I: Bolter, E., D. Hemphill, B. Wixson, D. Buthers, and R. Chen. Geochemical and Vegetation Studies on Trace Substances from Lead Smelting. In: Trace Substances in Environmental Health - VI, 1973. pp. 79-86.

Reference J: Robinson, A.V., T.R. Garland, G.S. Schneiderman, R.E. Wildung, and H. Drucker. Microbial Transformation of a Soluble Organo-plutonium Complex. In: Biological Implications of Metals in the Environment. Proceedings of the Fifteenth Annual Hanford Life Sciences Symposium at Richland, Washington, September 29-October 1, 1975. H. Drucker, and K.E. Wildung, eds. Sponsored by Battelle, Pacific Northwest Laboratories and Division of Biomedical and Environmental Research, Energy Research and Development Administration, Published by the Technical Information Center, Energy Research and Development Administration, Washington, D.C., 1977.



SNG/LPG
WATER VAPOR
CRYOGENIC SEPARATION
FUEL GAS
GAS PURIFICATION
HYDROGEN
RUM COAL
COAL PREPARATION
102
201
303
COAL/SOLVENT SLURRY
HYDROGENATION
PRODUCT SLURRY
TO GAS PURIFICATION
RAW WATER
AIR
AUXILIARY FACILITIES
101,103
104
301, 305-308
304
WATER TO PLANT USE
TREATED BLOWDOWN TO DISCHARGE
OXYGEN
STEAM
RECYCLED PROCESS SOLVENT
PHASE (GAS) SEPARATION
PROCESS WASTEWATER TO BY-PRODUCT RECOVERY
PRODUCT SLURRY
CONDENSED OILS
SOLID/LIQUID SEPARATION
HYDROGEN
COAL
HYDROGEN GENERATION
RESIDUE
302
LIQUID PRODUCT
TO GAS PURIFICATION
HYDROGEN
FRACTIONATION
TREATMENT FACILITIES
202, 103,104
302
FRACTIONATED PRODUCTS
HYDROTREATING
BY-PRODUCT RECOVERY
SOLIDIFICATION
LIQUID SRC
NAPHTHA
FUEL OIL
305
SULFUR
AMMONIA
PHENOL

Figure A-V-8. Diagrammatic representation of hypothetical SRC facility in White County, Illinois (12)

TABLE A-V-12. SAM/IA SUMMARY SHEET FOR THE HYPOTHETICAL SRC FACILITY DISCUSSED IN THIS REPORT

SAM/IA SUMMARY SHEET Form IA01

1. SOURCE AND APPLICABLE CONTROL OPTIONS
Hypothetical SRC-II facility using the control options described in the SRC Standards of Practice Manual

2. PROCESS THROUGHPUT OR CAPACITY 28,123 Mg Illinois No. 6 coal per day

3. USE THIS SPACE TO SKETCH A BLOCK DIAGRAM OF THE SOURCE AND CONTROL ITEMS SHOWING ALL EFFLUENT STREAMS. INDICATE EACH STREAM WITH A CIRCLED NUMBER USING 101-199 FOR GASEOUS STREAMS, 201-299 FOR LIQUID STREAMS, AND 301-399 FOR SOLID WASTE STREAMS.

See Figure A-V-11

4. LIST AND DESCRIBE GASEOUS EFFLUENT STREAMS USING RELEVANT NUMBERS FROM STEP 3.

101 Boiler flue gas
102 Coal preparation
103 Flare
104 Stretford Tail Gas
105
106
107

5. LIST AND DESCRIBE LIQUID EFFLUENT STREAMS USING RELEVANT NUMBERS FROM STEP 3.

201 Coal pile runoff
202 Foul process water
203
204
205
206

6. LIST AND DESCRIBE SOLID WASTE EFFLUENT STREAMS USING RELEVANT NUMBERS FROM STEP 3.

301 Raw water treatment sludge
302 SRC solid residue
303 Coal dust collected from control devices
304 API separator bottoms
305 Recovered sulfur
306 Bottom ash from steam generator
307. Bio-unit sludge
308. Fly-ash from steam generation

7. IF YOU ARE PERFORMING A LEVEL 1 ASSESSMENT, COMPLETE THE IA02-LEVEL 1 FORM FOR EACH EFFLUENT STREAM LISTED ABOVE. IF YOU ARE PERFORMING A LEVEL 2 ASSESSMENT, COMPLETE THE IA02-LEVEL 2 FORM FOR EACH EFFLUENT STREAM LISTED ABOVE.

(continued)

TABLE A-V-12. (continued)

8. LIST SUMS FROM LINE 7, FORMS IA02, IN TABLE BELOW

DEGREE OF HAZARD AND TOXIC UNIT DISCHARGE RATES BY EFFLUENT STREAM

GASEOUS					LIQUID					SOLID WASTE				
STREAM CODE	DEGREE OF HAZARD		TOXIC UNIT DISCHARGE RATES		STREAM CODE	DEGREE OF HAZARD		TOXIC UNIT DISCHARGE RATES		STREAM CODE	DEGREE OF HAZARD		TOXIC UNIT DISCHARGE RATES	
	HEALTH BASED	ECOL BASED	HEALTH BASED	ECOL BASED		HEALTH BASED	ECOL BASED	HEALTH BASED	ECOL BASED		HEALTH BASED	ECOL BASED	HEALTH BASED	ECOL BASED
	—	—	(m³/sec)			—	—	(l/sec)			—	—	(g/sec)	
101	2484		2.6E4	-	201	26	1127	D*	E*	301	43	44	24120	2495
102	2 -33	-	A*	-	202	F*	4950	G*	2.8E5	302	910	2.5E4	3.9E7	1.1E9
103	129	40	34	5.4						303	390	5.8E4	2.3E5	7.7E6
104	87-92	4-221	B*	C*						304	1892	3.9E4	H*	I*
										305	168	1692	8.6E5	8.7E6
										306	1597	5065	1.2E6	3.9E6
										307	697	29	4034	168
										308	6367	9.9E4	2.7E6	4.1E7
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O

9. SUM SEPARATELY GASEOUS, LIQUID AND SOLID WASTE STREAM DEGREES OF HAZARD FROM TABLE AT LINE 8 (I.E., SUM COLUMNS)

	TOTAL DEGREE OF HAZARD	
	HEALTH-BASED	ECOLOGICAL-BASED
GASEOUS	(Σ COL. B) 9A 2.7×10^3	(Σ COL. C) 9A' 44-221
LIQUID	(Σ COL. G) 9B 545-1245	(Σ COL. H) 9B' 6077.
SOLID WASTE	(Σ COL. L) 9C 12064	(Σ COL. M) 9C' 2.28×10^5

10. SUM SEPARATELY GASEOUS, LIQUID AND SOLID WASTE STREAM TOXIC UNIT DISCHARGE RATES FROM TABLE AT LINE 8 (I.E., SUM COLUMNS)

	TOTAL TOXIC UNIT DISCHARGE RATES	
	HEALTH-BASED	ECOLOGICAL-BASED
GASEOUS (m^3/sec)	(Σ COL. D) 10A $3.2\text{-}4.2 \times 10^4$	(Σ COL. E) 10A' 266-14515
LIQUID (l/sec)	(Σ COL. I) 10B $1.9\text{-}4.4 \times 10^4$	(Σ COL. J) 10B' 2.8×10^5
SOLID WASTE (g/sec)	(Σ COL. N) 10C 4.4×10^7	(Σ COL. O) 10C' 1.2×10^9

11. NUMBER OF EFFLUENT STREAMS

GASEOUS 11A 4

LIQUID 11B 2

SOLID WASTE 11C 8

12. LIST POLLUTANT SPECIES KNOWN OR SUSPECTED TO BE EMITTED FOR WHICH A MATE IS NOT AVAILABLE.

See the specific quantitation in Chapter 3 of this report.

*See footnote list.

Footnotes to Table A-V-12

A: 671-10,149[a]

B: 5,734-6,017[a]

C: 261-14,510[a]

D: 26-28[b]

E: 1,127-1,240[b]

F: 519-1,219[c]

G: 18,600-43,800[c]

H: 219-1,971[d]

I: 4,521-40,700[d]

In stream 306, cadmium is not included in ecology-based calculated values and zinc and vanadium are not included in any calculated values due to the uncertainty in the analysis of these materials.

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[a] The range shown by A, B, and C is due to differences in the efficiency of control technologies which may be applied.

[b] The range shown by D and E results from calculation of these values using two different techniques to estimate the runoff.

[c] The range shown by F and G results from uncertainty in quantitation of certain organic compounds.

[d] The range shown by H and I results from difficulty in estimation of the waste stream flow rate.

TABLE A-V-13. SAM/IA WORK SHEET FOR EFFLUENT STREAM NUMBER 201 (COAL PILE DRAINAGE) FOR THE HYPOTHETICAL SRC FACILITY DISCUSSED IN THIS REPORT

SAM/IA WORKSHEET FOR LEVEL 2

Form IA02 Level 2

1. SOURCE/CONTROL OPTION

Hypothetical SRC facility using the control options described in the SRC Standards of Practice Manual

Page 1 / 2

2. EFFLUENT STREAM

201 Coal Pile Drainage

CODE # NAME

3. EFFLUENT STREAM FLOW RATE

Q = 1.0-1.1 ℓ/sec

(gas = m³/sec — liquid = l/sec — solid = g/sec)

4. COMPLETE THE FOLLOWING TABLE FOR THE EFFLUENT STREAM OF LINE 2 (USE BACK OF FORM FOR SCRATCH WORK)

A		B	C	D	E	F	G	H	I	J
POLLUTANT SPECIES	CATEGORY	POLLUTANT CONCENTRATION	HEALTH MATE CONCENTRATION	ECOLOGICAL MATE CONCENTRATION	DEGREE OF HAZARD (HEALTH) (B/C)	DEGREE OF HAZARD (ECOLOGICAL) (B/D)	√ if HEALTH MATE EXCEEDED	√ if ECOL MATE EXCEEDED	TOXIC UNIT DISCHARGE RATE (HEALTH BASED) (E x LINE 3)	 (ECOLOGICAL BASED) (F x LINE 3)
UNITS	–	µg/l	µg/l	µg/l	—	—	—	—	ℓ/sec	ℓ/sec
Alkalinity		20,000								
BOD		3,300								
COD		8.2×10^5								
Total Dissolved Solids		1.3×10^7								
Total Suspended Solids		8.3×10^5								
Turbidity		2.0×10^5								
Acidity		9.9×10^6								
Total hardness		8.0×10^5								
pH		4.4								

IF MORE SPACE IS NEEDED, USE A CONTINUATION SHEET

5. EFFLUENT STREAM DEGREE OF HAZARD

HEALTH MATE BASED (Σ COL. E) 5a 25.7

ECOLOGICAL MATE BASED (Σ COL. F) 5b 1127.

(ENTER HERE AND AT LINE 8, FORM IA01)

6. NUMBER OF POLLUTANTS COMPARED TO MATES

HEALTH 6a 6

ECOLOGICAL 6b 6

7. TOXIC UNIT DISCHARGE SUM

HEALTH MATE BASED (Σ COL. I) 7a 25.7-28.3

ECOLOGICAL MATE BASED (Σ COL. J) 7b 1127-1240

(ENTER HERE AND AT LINE 8, FORM IA01)

(continued)

TABLE A-V-13. (continued)

CONTINUATION SHEET FOR ITEM NO. 4, FORM IA02, LEVEL 2 Page 2/2

SOURCE/CONTROL OPTION Hypothetical SRC Facility EFFLUENT STREAM NO 201

A		B	C	D	E	F	G	H	I	J
									TOXIC UNIT DISCHARGE RATE	
POLLUTANT SPECIES	CATEGORY	POLLUTANT CONCENTRATION	HEALTH MATE CONCENTRATION	ECOLOGICAL MATE CONCENTRATION	DEGREE OF HAZARD (HEALTH) (B/C)	DEGREE OF HAZARD (ECOLOGICAL) (B/D)	√ IF HEALTH MATE EXCEEDED	√ IF ECOL MATE EXCEEDED	(HEALTH BASED) (E x LINE 3)	(ECOLOGICAL BASED) (F x LINE 3)
UNITS	—	μg/l	μg/l	μg/l	—	—	—	—	ℓ/sec	ℓ/sec
Aluminum		1.0×10^6	80000.	1000.	12.5	1000	+	+	12.5-13.8	1000-1100
Chromium		2700.	250.	250.	10.8	10.8	+	+	10.8-11.9	10.8-11.9
Copper		2100.	5000.	50.	0.42	42		+	0.42-0.46	42-46
Magnesium		1.3×10^5	90000.	87000	1.4	1.5	+	+	1.4-1.6	1.5-1.6
Ammonia		690.	2500.	50.	0.3	13.8		+	0.28-0.30	13.8-15.2
Zinc		5900.	25000.	100	0.24	59.		+	0.24-0.26	59-65
Sulfate		5.9×10^6								
Chloride		1.3×10^5								
Iron		1.1×10^7								
Sodium		8.9×10^5								

(continued)

TABLE A-V-13. (continued)

NOTES

2.6E4 equivalent to 2.6 X 10^4

ASSUMPTIONS

LIST ALL ASSUMPTIONS MADE REGARDING FLOW RATE, EMISSION FACTORS AND MATE VALUES.

1. Assume no fugitive emissions.
2. For coal pile drainage for one calculation of the two presented, assume all the rain on the coal pile ran off.

is available which would indicate the identity and quantity of organic species in coal pile drainage. The volume of the coal pile runoff (Q) was estimated using the formula in Chapter 3, or by assuming all of the 102.8 cm precipitation (annual average at Carmi, Illinois) falling on a 3.24 ha coal pile actually ran off.

A-V.3 Cost for Environmental and Economic Impacts

Table A-V-14 shows the cost of the environmental and economic impacts of siting an SRC coal liquefaction facility in White County, Illinois.

TABLE A-V-14. COSTS FOR ENVIRONMENTAL AND ECONOMIC IMPACTS

Category[a]	Typical design options[b]	X: Impact Variable	Extrapolation[c] formula, type	Extrapolation parameters[d]	Remarks
Geology	All	Slope, percentage	Linear	y'_c=\$2.5/kWe/percent slope	Uses cost of earth-moving for average highways
Seismology	Nuclear	"g's" for safe shutdown earthquake	Logarithmic	$X(1)=0.15$ g $X(\infty) = 0.5$ g, $y(1) = \$10$/kWe	Rough estimate
Meteorology	Fossil	$\mu g/m^3$ or other concentration variables for pollutants	Step function	$X(\infty)$ = standards value	Use state and federal standards
Population:					
Population centers	Nuclear	Inverse distance, $mile^{-1}$	Logarithmic	$X(1)=0.25$ $mile^{-1}$ $X(\infty)=0.4$ mile-1 $Y(1)=$ \$2/kWe	2 months delay, @ \$$10^6$/month, used as surrogate measure
Population density	Nuclear	Persons/$mile^2$	Logarithmic	$X(1)=500$ $mile^{-2}$ $X(\infty)=1000$ $mile^{-2}$ $Y(1)$-\$2/kWe	2 months delay, @ \$$10^6$/month, used as surrogate measure
Hydrology:					
Floods	Nuclear	Depth below MPF level in feet (plus 1 foot)	Quadratic[d]	$Y'_c(X)=\$0.015\ (1 + 0.25X)$/kWe	Cost of levee building
Quality	All	Concentrations of pollutants	Step function	$X(\infty)$= standards value	Use state and federal standards
Supply Cost	All	Distance, height	(no formula; use graphic solution)	Use New York PSC curves	See additional reading, N.Y. State Public Service Commission
Ecosystems:					
Impingement and entrapment	Once through	Percentage of new water used	Logarithmic	$X(1)= 20.$ $X(\infty)= 30$, $Y(1)=$ \$70/kWe	Hypothetical cooling tower cost used as surrogate.
Migratory species	Once-through	Percentage of waterway impacted	Logarithmic	$X(1)=67$, $X(\infty)=80$, $Y(1)$=\$70/kWe	Hypothetical cooling tower costs used as surrogate

(continued)

TABLE A-V-14. (continued)

Category[a]	Typical design options[b]	X:Impact Variable	Extrapolation[c] formula, type	Extrapolation parameters[d]	Remarks
Habitats	All	Percent of habitat impacted	Logarithmic	World: X(∞) = 1, X(1) = 0.5 Nation: X(∞) = 5, X(1) = 2.5 State: X(∞) = 10, X(1) = 5 Y(1) = \$70/kWe (aquatic) Y(1) = \$70/kWe - p.A (terrestrial)	Cooling tower costs less cooling lake costs where applicable
Land Use:					
Special public areas,[e] direct	All	Co-location or conversion	Step function	X(∞)=0	No conversion allowed
Special public areas,[e] indirect	Cooling towers	Visual angle subtended, steradians	Logarithmic	X(1)=0.5 steradian X(∞)=1 steradian Y(1)=p.A[e]/-\$70 kWe	Hypothetical replacement of tower by lake
Specialty Cropland	Cooling lakes	Percentage of total specialty cropland	Logarithmic	World: X(∞)= 1, X(1) = 0.5 Nation: X(∞)=5 X(1)=2.5 State: X(∞)=10 X(1) =5 Y(1) = value of lost crop	Use revenue lost as approximation to disbenefit

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[a] Only those factors are shown that were approximately quantified or that represent legal standards.

[b] Design options will in general have more overlap than shown: a study of typical plant performance characteristics may be necessary.

[c] Formulas are given below in note d for the total cost y. Note extrapolation for many factors is tentative and could be replaced by other types of functions.

[d] Extrapolation formulas and parameters are: linear (or quadratic, for which $y'c = y'c(X)$): $y = y'c \cdot X$; Logarithmic: $y = y(1) \log (1 - (\infty))/\log (1 - X(1)/X(\infty))$; Step funtion: $y = 0$ for X (∞), y for X X (∞).

[e] p is the price of land, adjusted for construction costs where applicable. A is the acreage involved for a hypothetical or real cooling lake, plant, etc., as applicable.

REFERENCES

1. National Oceanic and Atmospheric Administration, National Climatic Center, Federal Building, Ashville, North Carolina, 1978.

2. Doty, S.R., B.L. Wallace and G.C. Holzworth. A Climatological Analysis of Pasquill Stability Categories Based on 'Star' Summaries. NOAA, National Climatic Center, Federal Building, Ashville, North Carolina, 1976.

3. Beck, R.W., and Associates. Environmental Analysis Merom Generating Station for Hoosier Energy Division of Indiana Statewide R.E.C., Inc., 1976.

4. Office of Solid Waste Management Program. The Report to Congress: Waste Disposal Practices and Their Effects on Ground Water. U.S. Environmental Protection Agency, Washington, D.C., 1977. 512 pp.

5. Weast, R.C. Handbook of Chemistry and Physics, 57th Edition, CRC Press, Cleveland, Ohio, 1976.

6. Bard, A.J. Chemical Equilibrium, Harper and Row, New York, 1966.

7. Unpublished information submitted to the U.S. Environmental Protection Agency under Contract No. 77-43-302073.

8. Bennett, H. Concise Chemical and Technical Dictionary. Chemical Publishing Company, Inc., New York, 1962.

9. Pauling, L. College Chemistry. W.H. Freeman and Company, San Francisco, California, 1957.

10. Stecher, P.G., M. Windholz, D.S. Leahy, D.M. Bolton and L.G. Eaton. The Merck Index. Merck and Company, Rahway, New Jersey, 1968.

11. Schalit, L.M., and K.J. Wolfe. SAM/IA: A Rapid Screening Method for Environmental Assessment of Fossil Energy Process Effluents. EPA-600/7-78-015, U.S. Environmental Protection Agency, Industrial Environmental Research Laboratory, Research Triangle Park, North Carolina, 1978.

12. Hittman Associates, Inc. Standards of Practice Manual for the Solvent Refined Coal Liquefaction Process, EPA 600/7-78-091, EPA Industrial Environmental Research Laboratory, Research Triangle Park, North Carolina, June 1978. 353 pp.

13. Ramsay, William. Siting Power Plants. Environ. Sci. and Technol. 11(3):238. 1977.

APPENDIX VI

POLLUTANTS OF CONCERN AND SUGGESTIONS FOR APPROPRIATE GOALS

A-VI POLLUTANTS OF CONCERN AND SUGGESTIONS FOR APPROPRIATE GOALS

A-VI.1 Introduction

As discussed in Appendices I and II, the background report for the MEGs represents the most thorough literature search uncovered to date. The MEGs are then derived from logical mathematical considerations using federal standards or original experimental data uncovered in this literature search to give numbers which indicate levels in waste streams (MATEs) or in environmental compartments (ambient level goals) which should not cause environmental harm. In particular, MEGs derived from original data are quite likely to give environmental goals which are "reasonable" in that these goals, if realized, will prevent further deterioration of the environment.

Since the MEGs represent the most thorough literature search and the best attempt uncovered to date to objectively define concentrations which would not cause environmental damage, they should be followed when setting environmental goals. The MEGs which have already been determined are found in Tables A-VI-1, A-VI-2, A-VI-3, and A-VI-4. In these listings, an "emission MATE" refers to the concentration in a gaseous waste stream emitted to the atmosphere, and an "effluent MATE" refers to a liquid waste stream which will end up in the waters in the environment. The term "selenium compounds (as selenium)" means that the selenium content of the material is given in the concentration calculation. For example, a concentration of 100 μg/l $SeCl_4$, molecular weight of 221.03, contains 35.72 μg/l Se, and it is this latter concentration to which the MEGs would refer. A "nutrient solution" in the case of a terrestrial plant, may mean that the plant was grown in the solution or that

TABLE A-VI-1. MEGs FOR INORGANIC AIR POLLUTANTS (UNITS ARE MICROGRAMS PER CUBIC METER)

	MATE		AMBIENT LEVEL GOAL	
Element	Based on Health Effects	Based on Ecological Effects	Based on Health Effects	Based on Ecological Effects
Aluminum and compounds[a]	5,200.		12.6	
Aluminum oxide (Al_2O_3)	10,000.		24.	
Antimony and compounds[a]	500.		1.2	
Antimony Trioxide (Sb_2O_3)	50.		0.1	
Arsenic and compounds	2.0		0.005	
Barium and compounds	500.		1.	
Beryllium and compounds	2.0		0.001	
Bismuth and compounds	410.		0.7	
Boron and compounds[a]	3,100.		74.	
Boron oxide (B_2O_3)	10,000.		24.	
Bromine and compounds [Except elemental Bromine (Br_2)[d]]	>450.[c]		>1.1[c]	
Cadmium and compounds	10.[b]		0.02	
Calcium and compounds	>450.[c]		>1.1[c]	
Carbon				
Carbonyl sulfide (COS)	4.4×10^5		800.	
Carbon monoxide (CO)	40,000.	1.2×10^5	10,000.	10,000.
Carbon dioxide (CO2)	9.0×10^6			
Carbon disulfide (CS_2)	60,000.[b]		143.	
Cesium and compounds	>450.[c]		>1.1[c]	
Chlorine and compounds (Except ClO^{-}[d], ClO_3^{-}[d], Cl_2[d] or hydride[d])	>450.[c]		>1.1[c]	
Chromium and compounds	1.0		0.002	
Cobalt and compounds	50.		0.1	
Copper and compounds[a]	200.		0.5	
Copper 8-hydroxyquinoline [($C_{13}H_{12}N_2O_2Cu$) (8-quinolinol Copper II chelate)]	3,000.		5.	
Gallium and compounds	5,000.		9.	
Germanium and compounds	560.		1.3	
Hafnium and compounds	>45.[c]		>0.11[c]	
Iodine and compounds (Except Hydride[d])	>45.[c]		>0.11[c]	
Iron and compounds[a]	>4.5[c]		>0.011[c]	
Ferrocene $[(\pi C_5H_5)_2Fe]$	60,000.		107.	
Lanthanium and compounds	>45.[c]		>0.11[c]	

(continued)

TABLE A-VI-1. (continued)

Element	MATE		AMBIENT LEVEL GOAL	
	Based on Health Effects	Based on Ecological Effects	Based on Health Effects	Based on Ecological Effects
Lead and compounds[a]	150.[b]		0.36	
Tetraethyllead [$(C_2H_5)_4Pb$]	100.[b]		0.24	
Lithium and compounds[a]	22.		0.05	
Lithium hydride (LiH)	25.		0.06	
Magnesium and compounds[a]	6,000.		14.	
Magnesium oxide (MgO)	10,000.		24.	
Manganese and compounds	5,000.[b]		12.	
Mercury and compounds[a]	50.	10.	0.01	1.
Alkyl mercury (R_xHg)	10.		0.024	
Molybdenum and compounds	5,000.		12.	
Neodymium and compounds	>45.[c]		>0.11[c]	
Nickel and compounds[a]	15.		0.035	
Nickel carbonyl [$Ni(CO)_4$][d]	43.		0.1	
Nickelocene [$(\pi\text{-}C_5H_5)_2Ni$]	3,500.		8.	
Nitrogen and compounds				
Ammonia (NH_4)	18,000.[b]	350.	43.	35.
Hydrogen cyanide (HCN)	11,000.	34,000.	26.	3,400.
Sodium or Potassium cyanide (NaCN or KCN)	5,000.		12.	
Hydrazine (H_2NNH_2)	150.		0.36	
Ozone (O_3)	200.[b]	10.	160.[b]	160.[b]
Phosphorous and compounds				
Elemental phosphorous (P)	100.[b]		0.24[b]	
Phosphine (PH_3)	400.		0.95	
Polonium and compounds[d]	>0.[c]		>0.[c]	
Potassium and compounds	2,000.		5.	
Praseodymium and compounds	>45.[c]		>0.11[c]	
Rubidium and compounds (except oxides[d])	>45.[c]		>0.11[c]	
Samarium and compounds	>45.[c]		>0.11[c]	
Scandium and compounds	53,000.		96.	
Selenium and compounds[a]	200.		0.03	
Hydrogen selenide (H_2Se)	200.		0.5	
Silicon and compounds	>45.[c]		>0.11[c]	
Silver and compounds	10.		0.024	
Sodium and compounds	>450.[c]		>1.1[c]	
Strontium and compounds	3,000.		5.5	
Sulfur and compounds				
Hydrogen sulfide (H_2S)	15,000.		36.[b]	

(continued)

TABLE A-VI-1. (continued)

	MATE		AMBIENT LEVEL GOAL	
Element	Based on Health Effects	Based on Ecological Effects	Based on Health Effects	Based on Ecological Effects
Tantalum and compounds	>45.[c]		>0.11[c]	
Tellurium and compounds	100.		0.24	
Thallium and compounds	100.		0.24	
Thorium and compounds	>45.[c]		>0.11[c]	
Tin and compounds[a]				
Organotin compounds	100.		0.24	
Tin hydride (SnH_4)[d]	>0.[c]		>0.[c]	
Titanium and compounds	6,000.[b]		14.	
Tungsten and compounds	1,000.		2.4	
Uranium and compounds	9.		0.5	
Vanadium and compounds	500.[b]	1.	1.2[b]	0.1
Ytterbium and compounds	>45.[c]		>0.11[c]	
Yttrium and compounds	>45.[c]		>0.11[c]	
Zinc and compounds	4,000.		9.5	
Zirconium and compounds	>4.5[c]		>0.011[c]	

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[a] Except as noted below.

[b] These MEG values may be "unreasonable." They are dealt with on an individual basis in the text.

[c] Estimated from the information contained in Table VI-2.

[d] This compound (or element) is very toxic and should not be tolerated. Also included in this group are the rarer radioactive elements including radium and radon.

TABLE A-VI-2. MEGs FOR INORGANIC WATER POLLUTANTS (UNITS ARE MICROGRAMS PER MILLILITER)

Element	MATE		AMBIENT LEVEL GOAL	
	Based on Health Effects	Based on Ecological Effects	Based on Health Effects	Based on Ecological Effects
Aluminum and compounds[a]	80,000.[b]	1,000.[b]	73.	200.[b]
Aluminum oxide (Al_2O_3)	1.5×10^5		138.	
Antimony and compounds[a]	7,500.	200.	7.	40.
Antimony Trioxide (Sb_2O_3)	7,500.	200.	1.5	40.
Arsenic and compounds	250.	50.		10.
Barium and compounds	5,000.	2,500.	1,000.	500.
Beryllium and compounds	30.	55.	0.075	11.[b]
Bismuth and compounds	6,100.		3.6	
Boron and compound[a]	4.7×10^4[b]	3,800.[b]	43.	750.[b]
Boron oxide (B_2O_3)	1.5×10^5[b]		138.	
Bromine and compounds [(Except elemental Bromine (Br_2)[d]]	>6,750.[c]		>160.[c]	
Cadmium and compounds	50.[b]	1.0[b]	10.[b]	0.4[b]
Calcium and compounds	6,750.[c]		160.[c]	
Carbon				
Carbon monoxide (CO)	6.0×10^5	60.	552.	30.
Carbon disulfide (CS_2)	9.0×10^5	10,000.	830.	5,000.
Cesium and compounds	>6,750.[c]		>160.[c]	
Chlorine and compounds (Except ClO^-[d], ClO_3^-[d], Cl_2[d] or hydride[d])	>6,750.[c]		>160.[c]	
Chromium and compounds	250.	250.	50.[b]	50.[b]
Cobalt and compounds	750.[b]	250.[b]	0.7	50.[b]
Copper and compounds[d]	5,000.[b]	50.	1,000.[b]	10.
Copper 8-hydroxyquinoline [($C_{13}H_{12}N_2O_2Cu$)(8-quinolinol copper II chelate)]	45,000.		27.	
Gallium and compounds	74,000.		44.	
Germanium and compounds	8,400.		8.	
Hafnium and compounds	>675.[c]		>1.6[c]	
Iodine and compounds (Except Hydride[d])	>675.[c]		>1.6[c]	
Iron and compounds[d]	67.5[c]		0.16[c]	
Ferrocene [$(\pi\text{-}C_5H_5)_2Fe$]	9.0×10^5		530.	
Lanthanium and compounds	>675.[c]		>1.6[c]	
Lead and compounds[a]	250.	50.	50.[b]	10.
Tetramethyllead [$(CH_4)_4Pb$]	2,250.		2.	
Tetraethyllead [$(C_2H_6)_4Pb$]	1,500.[b]	100.[b]	1.6	50.[b]

(continued)

TABLE A-VI-2. (continued)

Element	MATE Based on Health Effects	 Based on Ecological Effects	AMBIENT LEVEL GOAL Based on Health Effects	 Based on Ecological Effects
Lithium and compounds[a]	330.	375.	0.3	75.
Lithium hydride (LiH)	375.		0.3	
Magnesium and compounds[a]	90,000.[b]	87,000.[b]	83.	43,300.[b]
Magnesium oxide (MgO)	1.5×10^5	1.0×10^5	138.	50,000.
Manganese and compounds	250.	100.	50.	20.
Mercury and compounds[a]	10.[b]	250.[b]	2.[b]	50.[b]
Alkyl mercury (R_xHg)	150.	0.02	0.14[b]	0.01[b]
Molybdenum and compounds	75,000.[b]	7,000.[b]	70.	1,400.
Neodymium and compounds	>675.[c]		>1.6[c]	
Nickel and compounds[a]	230.[b]	10.[b]	0.6[b]	2.[b]
Nickel carbonyl $[Ni(CO)_4]$	650.	10.	1.5	2.
Nickelocene $[(\pi\text{-}C_5H_5)_2Ni]$	52,000.		120.	
Nitrogen and compounds				
Ammonia (NH_4)	2,500.	50.	500.	10.
Hydrogen cyanide (HCN)	500.[b]	25.[b]	100.[b]	5.
Sodium or Potassium cyanide (NaCN or KCN)	500.[b]	25.[b]	100.[b]	
Hydrazine (H_2NNH_2)	2.3		5.4	
Phosphorous and compounds				
Elemental phosphorous (P)	15,000.	0.5	1.4	0.1
Phosphine (PH_3)	6,000.		5.5	
Polonium and compounds[d]	>0.[c]		>0.[c]	
Potassium and compounds	3.0×10^4	4.3×10^4	75.	21,600.
Praseodymium and compounds	>675.[c]		>1.6[c]	
Rubidium and compounds (except oxides[d])	>675.[c]		>1.6[c]	
Samarium and compounds	>675.[c]		>1.6[c]	
Scandium and compounds	8.0×10^5		474.	
Selenium and compounds	50.	25.	10.	5.
Silicon and compounds	>675.[c]		>1.6[c]	
Silver and compounds	250.[b]	5.[b]	50.[b]	5.[b]
Sodium and compounds	>6,750.[c]		>160.[c]	
Strontium and compounds	46,000.		27.	
Sulfur and compounds				
Hydrogen sulfide (H_2S)	23,000.[b]	10.[b]	207.[b]	2.[b]

(continued)

TABLE A-VI-2. (continued)

Element	MATE Based on Health Effects	 Based on Ecological Effects	AMBIENT LEVEL GOAL Based on Health Effects	 Based on Ecological Effects
Tantalum and compounds	>675.[c]		>1.6[c]	
Tellurium and compounds	1,500.		1.4	
Thallium and compounds	1,500.[b]		1.4[b]	
Thorium and compounds	>675.[c]		>1.6[c]	
Tin and compounds[a]				
Organotin compounds	1,500.		1.4	
Tin hydride (SnH_4)[d]	>0.[c]		>0.[c]	
Titanium and compounds	90,000.[b]	820.	83.	4,100.
Tungsten and compounds	15,000.		14.	
Uranium and compounds	60,000.[b]	500.	3.	100.
Vanadium and compounds	2,500.[b]	150.	7.	75.
Ytterbium and compounds	>675.[c]		>1.6[c]	
Yttrium and compounds	>675.[c]		>1.6[c]	
Zinc and compounds	25,000.[b]	100.	5,000.[b]	20.
Zirconium and compounds	>67.5[c]		>0.16[c]	

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[a] Except as noted below.

[b] These MEG values may be "unreasonable." They are dealt with on an individual basis in the text.

[c] Estimated from the information contained in Table VI-2.

[d] This compound (or element) is very toxic and should not be tolerated. Also included in this group are the rarer radioactive elements including radium and radon.

(continued)

TABLE A-VI-3. MEGs FOR INORGANIC SOLID WASTES (UNITS ARE MICROGRAMS PER GRAM)

Element	MATE		AMBIENT LEVEL GOAL	
	Based on health effects	Based on ecological effects	Based on health effects	Based on ecological effects
Aluminum and compounds[a]	16,000.	200.	15.	40.
Aluminum oxide (Al_2O_3)	30,000.		30.	
Antimony and compounds[a]	1,500.	40.	1.4	8.
Antimony trioxide (Sb_2O_3)	150.	40.	0.3	8.
Arsenic and compounds	50.	10.	10.	2.
Barium and compounds	1,000.	500.	20.	10.
Beryllium and compounds	6.0	11.	0.015	1.
Bismuth and compounds	1,200.		0.7	
Boron and compounds[a]	9,300.	5,000.	9.	1,000.
Boron oxide (B_2O_3)	30,000.		30.	
Bromine and compounds [(Except elemental bromine (Br_2)[d]]	>1,350.[c]		>3.[c]	
Cadmium and compounds	10.	0.2	0.06	0.04
Calcium and compounds	>1,350.[c]		>3.[c]	
Cesium and compounds	>1,350.[c]		>3.[c]	
Chlorine and compounds (Except ClO^-[d], ClO_3^-[d], Cl_2[d] or hydride[d])	>1,350.[c]		>3.[c]	
Chromium and compounds	50.	50.	0.01	10.
Cobalt and compounds	150.	50.	0.1	10.
Copper and compounds[a]	1,000.	10.	20.	20.
Copper 8-hydroxyquinoline [($C_{13}H_{12}N_2O_2Cu$)(8-quinolinol copper II chelate)]	9,000.		5.4	
Gallium and compounds	15,000.		9.	
Germanium and compounds	1,700.		1.6	
Hafnium and compounds	>1,350.[c]		>0.3[c]	
Iodine and compounds (Except hydride[d])	>135.[c]		>0.3[c]	
Iron and compounds[a]	>13.5[c]		>0.03[c]	
Ferrocene [$(\pi\text{-}C_5H_5)_2Fe$]	180,000.		100.	
Lanthanium and compounds	>135.[c]		>0.3[c]	

(continued)

TABLE A-VI-3. (continued)

Element	MATE		AMBIENT LEVEL GOAL	
	Based on health effects	Based on ecological effects	Based on health effects	Based on ecological effects
Lead and compounds[a]	50.	10.	1.	2.
Tetramethyllead [$(CH_4)_4Pb$]	450.		0.4	
Tetraethyllead [$(C_2H_6)_4Pb$]	300.	20.	0.3	10.
Lithium and compounds[a]	70.	70.	0.06	15.
Lithium hydride (LiH)	75.		0.06	
Magnesium and compounds[a]	18,000.	17,400.	20.	8,700.
Magnesium oxide (MgO)	30,000.	20,000.	30.	10,000.
Manganese and compounds	50.	20.	10.	4.
Mercury and compounds[a]	2.	50.	0.4	10.
Alkyl mercury (R_xHg)	30.	0.004	0.03	0.002
Molybdenum and compounds	15,000.[b]	1,400.[b]	14.[b]	2.[b]
Neodymium and compounds	>135.[c]		>0.3[c]	
Nickel and compounds[a]	45.	2.	0.1	0.4
Nickel carbonyl [$Ni(CO)_4$]	130.	2.	0.3	0.4
Nickelocene [$(\pi\text{-}C_5H_5)_2Ni$]	10,000.		20.	
Nitrogen and compounds				
Ammonia (NH_4)	500.	10.	100.	2.
Hydrogen cyanide (HCN)	100.	5.0	20.	1.
Sodium or potassium cyanide (NaCN or KCN)	100.	5.	20.	1.
Hydrazine (H_2NNH_2)	450.		1.	
Phosphorus and compounds				
Elemental phosphorus (P)	3,000.	0.1	0.3	0.02
Polonium and compounds[d]	>0.[c]		>0.[c]	
Praseodymium and compounds	>135.[c]		>0.3[c]	
Rubidium and compounds (Except oxides[d])	>135.[c]		>0.3[c]	
Samarium and compounds	>135.[c]		>0.3[c]	
Scandium and compounds	160,000.		90.	
Selenium and compounds	10.[b]	5.0[b]	2.[b]	1.[b]
Silicon and compounds	>135.[c]		>0.3[c]	
Silver and compounds	0.5	0.01	0.1	0.01
Sodium and compounds	>1,350.[c]		>3.[c]	
Strontium and compounds	9,200.		5.	
Tantalum and compounds	>135.[c]		>0.3[c]	
Tellurium and compounds	300.		0.3	

(continued)

TABLE A-VI-3. (continued)

Element	MATE		AMBIENT LEVEL GOAL	
	Based on health effects	Based on ecological effects	Based on health effects	Based on ecological effects
Thallium and compounds	300.		0.3	
Thorium and compounds	>135.[c]		>0.3[c]	
Tin and compounds[a]				
Organotin compounds	300.		0.3	
Tin hydride (SnH_4)[d]	>0.[c]		>0.[c]	
Titanium and compounds	18,000.	160.	17.	800.
Tungsten and compounds	3,000.		3.	
Uranium and compounds	12,000.	100.	0.6	20.
Vanadium and compounds	500.	30.	1.4	15.
Ytterbium and compounds	>135.[c]		>0.3[c]	
Yttrium and compounds	>135.[c]		>0.3[c]	
Zinc and compounds	5,000.	20.	1,000.	4.
Zirconium and compounds	>13.5[c]		>0.3[c]	

[a] Except as noted below.

[b] These MEG values may be "unreasonable." They are dealt with on an individual basis in the text.

[c] Estimated from the information contained in Table VI-2.

[d] This compound (or element) is very toxic and should not be tolerated. Also included in this group are the rarer radioactive elements including radium and radon.

TABLE A-VI-4. MULTIMEDIA ENVIRONMENTAL GOALS FOR ORGANIC CATEGORIES, USING LOWEST MEG VALUES LISTED FOR EACH CATEGORY OF COMPOUNDS

	Emission level goals - based on ambient factor												
	Minimum acute toxicity effluent						Ambient level goal						
Compound	Based on health effects			Based on ecological effects			Based on health effects			Based on ecological effects			
	Air $\mu g/m^3$	Water $\mu g/l$	Land $\mu g/g$	Air $\mu g/m^3$	Water $\mu g/l$	Land $\mu g/g$	Air $\mu g/m^3$	Water $\mu g/l$	Land $\mu g/g$	Air $\mu g/m^3$	Water $\mu g/l$	Land $\mu g/g$	
1. Aliphatic hydrocarbons	$1.4x10^6$	$2.1x10^7$		1.0	$1.0x10^5$		3,450	$1.9x10^4$			$<5x10^4$		
2. Alkyl halides*	$2.1x10^5$	$3.2x10^6$	$6.4x10^5$		$1.0x10^5$	20,000.	500	2,900	580.		50,000	10,000.	
Vinyl chloride	$2.55x10^4$	$3.8x10^4$	7,600.		$1.0x10^5$	20,000.	6	90	20.		<50,000	10,000.	
3. 1,4-Dioxane	$1.8x10^5$	$2.7x10^6$	$5.4x10^5$		$1.0x10^4$	2,000.	428	2,480	30.		5,000	1,000.	
4. Halogenated ethers	$3x10^4$	$4.5x10^5$	90,000.		$1.0x10^4$	2,000.	71	414	80.		5,000	1,000.	
5. Alcohols	$1.8x10^4$	$2.7x10^5$	54,000.				37	160	30.		5,000	1,000.	
6. Glycols, epoxides	$1.0x10^4$	$1.5x10^5$	30,000.		1,000	200.	24	140	3.		500	100.	
7. Aldehydes, ketones*	$2.5x10^4$	$3.75x10^5$	75,000.		100	20.	60	345	70.		<50	10.	
Formaldehyde	$1.6x10^3$	$2.4x10^4$	4,800.	500	1,000	200.	3.9	41.4	8.	49	500	100.	
Acrolein	250	3,750	750.	94	100	20.	0.6	3.5	0.7	9	50	10.	
8. Carboxylic acid & derivatives*	$6x10^3$	$9x10^4$	18,000.		1,000	200.	14	83	20.		500	100.	
Phthalate esters	$5x10^3$	$7.5x10^4$	15,000.		1.5	0.3	12	69	14.		0.3	0.06	
9. Nitriles	$3x10^3$	$4.5x10^4$	9,000.		1,000	20.	7	41	8.	500	1		
10. Amines*	$6x10^3$	$9x10^4$	18,000.		$1.0x10^3$	20.	14	83	17.		500	100.	
Aminotoluenes	110	$1.65x10^3$	300.				0.26	4	0.8				
4-Aminobiphenyl	$1.3x10^3$	$2x10^4$	4,000.				3	45	10.				
1-Aminonaphthalene	564	$8.5x10^3$	1,700.		100	20.	1.3	20	4.		50	10.	
2-Aminonaphthalene	165	$2.5x10^3$	500.		100	20.	0.4	6	1.2		50	10.	
Ethyleneimine	332	$5x10^3$	1,000.				0.8	12	2.4				
11. Azo compounds:* hydrazine derivatives	350	$5.25x10^3$	1,100.				0.8	5	1.				
N,N'-dimethylhydrazine	32	500	1,000.				0.075	1.1	0.2				
12. Nitrosamines													
N-nitrosodimethylamine	1.2	18	36.				0.003	0.045	0.009				
n-nitrosodiethylamine	120	$1.8x10^3$	360.				0.29	4.4	0.9				
13. Thiols	$1.0x10^3$	$1.5x10^4$	3,000.				2.4	13.8	3.				
14. Sulfonic acids; sulfoxides	$4x10^4$	$6x10^5$	$1.2x10^5$				72	156	20.				
15. Benzene, substituted benzene hydrocarbons	$1.0x10^3$	$1.5x10^4$	3,000.		1,000	200.	2.4	13.8	3.		250	50.	
16. Halogenated aromatic compounds*	$5x10^3$	$7.5x10^4$	150.		100	20.	12	69	14.		50	10.	
Polychlorinated biphenyls	500	$7.5x10^3$	1,500		0.005	0.001	1.2	7	1.4		0.001	0.0002	
17. Aromatic nitro compounds	$1.3x10^3$	$2x10^4$	4,000.		1,000	200.	3	45	10.		500	100.	
18. Phenols	$1.3x10^4$	5.0	1.		500	100.	24	1	0.2		70	10.	

(continued)

TABLE A-VI-4. (continued)

Compound	Emission level goals - based on ambient factor											
	Minimum acute toxicity effluent						Ambient level goal					
	Based on health effects			Based on ecological effects			Based on health effects			Based on ecological effects		
	Air $\mu g/m^3$	Water $\mu g/1$	Land $\mu g/g$	Air $\mu g/m^3$	Water $\mu g/1$	Land $\mu g/g$	Air $\mu g/m^3$	Water $\mu g/1$	Land $\mu g/g$	Air $\mu g/m^3$	Water $\mu g/1$	Land $\mu g/g$
19. Halophenols	7×10^{3}	5.0	1.		500	100.	17	1	0.1		0.1	0.001
20. Nitrophenols*	1,350	5.0	1.		500	100.	2.4	1	0.2		50	10.
4,6-dinitro-o-cresol	200	5.0	1.		500	100.	0.5	1	0.2		50	10.
2,4,6-trinitrophenol	100	5.0	1.		500	100.	0.24	1	0.2		100	20.
21. Fused polycyclic* hyd ocarbon	1,080	1.6×10^{4}	3,200.				2.6	39	9.			
Benz(a)anthracene	45	670	130.				0.11	1.65	0.3			
7,12-dimethylbenz(a) anthracene	0.26	3.9	0.8				0.0006	0.0009	0.018			
Dibenzo(a,h)anthracene	0.093	1.4	0.3				0.0002	0.003	6×10^{-4}			
Benzo(a)pyrene	0.02	0.3	0.6				5×10^{-5}	0.00075	1.5×10^{-4}			
Dibenzo(a,i)pyrene	43	650	130.				0.1	1.5	0.3			
22. Fused non-alternate polycyclic hydrocarbons	900	1.34×10^{6}	2,700.				2.1	31.5	6.			
3-methylcholanthrene	3.8	56	11.				0.009	0.14	0.03			
23. Heterocyclic nitrogen* compounds	2.7×10^{3}	9×10^{4}	810.				5	24	5.			
Dibenz(a,j)acridine	246	3.7×10^{3}	740.				0.59	8.85	2.			
Dibenz(a,h)acridine	220	3.36×10^{3}	670.				0.53	8.0	1.6			
Dibenzo(c,g)carbazole	103	1.5×10^{3}	300.				0.24	3.6	0.7			
24. Heterocyclic oxygen compounds tetrahydrofuran	5.9×10^{5}	9.0×10^{6}	1.6×10^{6}				1,400	8,100	1,600.			
25. Heterocyclic S compounds	2.25×10^{4}	3.4×10^{5}	70,000.				8	40	8.			

*MEG values listed for compound category exclude the more hazardous substances (which are listed individually), except where no other MATE values are given.

the solution was added to the soil in which the plant was growing. However, the exact meaning of this term is usually open to question. In some cases, the MEG had not been determined because the substance in question had not been subjected to MEG analysis, or because the information necessary to determine the MEG was not available. When possible, a subjective estimate of the environmental levels which would not present an environmental hazard has been given.

The MEG for organics (Table A-VI-4) is arranged by the category of compounds as determined by the MEG methodology. For each category the lowest MEG of the assessed compounds within that category (excluding compounds listed individually) is listed under the MEG category heading. In the following circumstances the MEGs of individual compounds are listed separately:

- When a compound is given a high hazard potential value (see Table A-II-5)
- When the span between the lowest and the next lowest MATE value in a MEG category is not within 1-2 orders of magnitude of each other.

The authors of the present report have attempted to update the MEG values with more recent information from the literature. Although this literature search was less extensive than the MEG search, some recent information was uncovered which will undoubtedly be included in updated versions of the MEGs. This information is outlined below.

A-VI.2 Air

A-VI.2.1 Inorganic

A-VI.2.1.1 Cadmium (Cd) (2,3)

Inhalation of 10 to 270 $\mu g/m^3$ cadmium has resulted in pulmonary and renal effects for exposed workers. In the range of zero to 0.062 $\mu g/m^3$ there appears to be a significant correlation ($r=0.76$ with 26 degrees of freedom or p less than 0.001; i.e., less than 1 chance in 10,000 that the observed correlation is due solely to chance) between the cadmium concentration and diseases of the heart. In view of this, the Illinois Institute for Environmental Quality recommends a 24-hour average cadmium level of 0.05 $\mu g/m^3$.

A-VI.2.1.2 Carbon Disulfide (CS_2) (2)

Human central nervous system damage has resulted from chronic exposure (for seven years) to a concentration of 50,000 $\mu g/m^3$.

A-VI.2.1.3 Fluorine and Fluorides (F) (2,4,5)

The emission MEGs for fluorides have not yet been calculated. Fluorine at levels greater than 2000 $\mu g/m^3$ acts as a direct cellular poison by interfering with calcium metabolism and enzyme mechanisms. Nosebleed, cough, irritation of the respiratory tract and of the eye are usually associated with 8-hour exposures greater than 2500 $\mu g/m^3$. However, several studies suggest that some of these effects can occur at levels down to 240 $\mu g/m^3$. The results of studies in and adjacent to aluminum facilities in the USA, Scotland, and the USSR are given in Table A-VI-5. Airborne fluorides are injurious to corn, sorghum, tomatoes, soybeans,

TABLE A-VI-5. FLUORIDE EFFECTS ON MAN IN RELATION TO AIR CONCENTRATIONS IN OR NEAR ALUMINUM PLANTS

Atmospheric concentration	Urinary fluoride	Comments
2400 to 6000 $\mu g/m^3$ (potroom)	8.7-9.8 mg/l	Morbidity rate of potroom workers, except for osteoarthritis and restricted elbows, varied little from other employees in plant. Arthritis, probably traumatic arthritis, was not from fluorides. X-rays indicated slight to severe skeletal fluorosis in 76 of 107 potroom workers, but cases were asymptomatic. 26 had advanced fluorosis with marked restriction of spinal movement.
3150 $\mu g/m^3$ one plant, 2340 $\mu g/m^3$ or less in another		X-ray examination of 10 pot workers with 7-30 yr. experience showed generalized osteosclerosis (not incapacitating) in 2, and areas of localized densification in 3.
140 to 3430 $\mu g/m^3$ (furnace rooms)	9.03 mg/24 hr (full time) male 5.19 mg/24 hr (part time) male 3.64 mg/24 hr (part time) female	25.4% incidence of X-ray abnormalities among 189 workers; 12.8% incidence of cough.
15 to 141 $\mu g/m^3$ (elsewhere in plant)	1.83 mg/24 hr male 1.58 mg/24 hr female	8.3% incidence of x-ray abnormalities among 60 workers; 6.9% incidence of cough.
33 to 40 $\mu g/m^3$ (control room)	0.84 mg/24 hrs male and female	4.0% incidence of x-ray abnormalities among 75 subjects.

(continued)

TABLE A-VI-5. (continued)

Atmospheric concentration	Urinary fluoride	Comments
22-42 μg/m^3 (0.18 to 1.6 km from factory)		No clinical signs or symptoms found among local residents, incidence of mottled teeth in children not appreciably different from that in unaffected areas.
ca. 40 μg/m^3 (1.6 to 2.4 km from a different factory)		No abnormal x-rays. Some teeth mottling.
600 μg/m^3 (0.5 km from factory)		Floral damage and window etching.

gladioli and a variety of other plants. The Illinois Institute for Environmental Quality recommends a fluoride standard of 0.7 $\mu g/m^3$, based on a 24-hour average. This value may be a bit stringent, since the health effects are observed only at much higher concentrations. Furthermore, atmospheric dilution of factory emissions may occur before floral contact.

A fluoride emission level of 25 $\mu g/m^3$ should prevent the adverse health effects to persons living near the plant; however, the effect of this fluoride level on cash crops at some distance from the facility is not known and will probably have to be determined on a site-specific basis.

A-VI.2.1.4 Lead (Pb) (2,3,4)

At concentrations greater than 150 $\mu g/m^3$ lead fumes and dusts act as a cumulative poison producing behavioral disorders, brain damage, convulsions and even death. At 1 $\mu g/m^3$, airborne lead produces altered metabolic effects. The Illinois Institute for Environmental Quality recommends a maximum level of 1.5 $\mu g/m^3$, based on a 24-hour average sample. Adjusting this for an eight-hour-per-day exposure gives about 4.5 $\mu g/m^3$ for eight hours and none for the next 16 hours.

A-VI.2.1.5 Manganese (Mn) (2,4,6)

Manganese oxides in the air have the capacity to act as catalysts in the oxidation of sulfur dioxide (SO_2) to sulfur trioxide (SO_3) which, in the presence of moisture, results in the formation of sulfuric acid and airborne sulfates. Recent studies have shown that suspended sulfates are considerably more irritating than either sulfur dioxide or total suspended particulates.

The toxic effects from particulate sulfates formed via manganese catalytic action with SO_2 will occur significantly before any direct toxic effects caused by ambient manganese. It was calculated that a conversion rate of approximately 0.12 percent could be achieved if the manganese level was 0.006 $\mu g/m^3$. This rate approaches the rate of non-catalytic conversion of sulfur dioxide to sulfuric acid (this rate is approximately 0.1 percent). Based on this information, the recommendation was made by the Environmental Health Resources Center in Illinois that the environmental standard for particulate manganese should be 0.006 $\mu g/m^3$.

This ambient air quality standard of 0.006 $\mu g/m^3$ will also provide protection to individuals who, because of a disease, metabolic disorder, or psychological disturbance, are more susceptible to direct manganese toxicity than the general population. Individuals with anemia, psychiatric disorders, and sensitivities to avitaminosis, liver dysfunction, and pulmonary infections are among those who may be more susceptible to the toxic effects of manganese.

Manganese levels at 500 $\mu g/m^3$ reportedly lead to emotional instability, apathy, hallucinations, compulsive acts, muscular hypertonia, muscular fatigue, and sexual depression. Levels as low as 20 $\mu g/m^3$ reportedly lead to tremors, facial masking, and reduced blinking. Levels of 100 $\mu g/m^3$ may lead to progressive weakness. These data relate to occupational exposures. It is well to note in this regard that occupational exposures are usually on an 8-hour day, 5-day per week basis, where off-work hours and weekends constitute recovery time from the health effects of hazardous materials.

A-VI.2.1.6 Nickel (Ni) (2,7)

Nickel carbonyl causes death after 30-minute exposure to a dose of 30 μg/g. Nickel carbonyl has been implicated as a respiratory carcinogen. Fortunately, nickel carbonyl is an extremely labile compound and is subject to photolysis, air oxidation and other forms of degradation.

A-VI.2.1.7 Nitrogen

A-VI.2.1.7.1 Ammonia (NH_3) (2)

The most sensitive plant species studied thus far appears to be the mustard plant. Four-hour exposure to 2,100 $\mu g/m^3$ of ammonia caused 15 percent marking of the leaf surface. Irritation has been reported in humans at levels of 14,400 $\mu g/m^3$.

A-VI.2.1.7.2 Nitrogen oxides (NO_x) (4,8)

The emission MEG values for this class of pollutants have not yet been determined. Nitrogen dioxide at levels greater than 5 ppm in ingested material, or 9,000 $\mu g/m^3$ cause corrosion as well as irritation of skin, eyes, digestive tract, or lungs following ingestion or inhalation. At concentrations of less than 1 ppm (1,200 $\mu g/m^3$) nitrogen dioxide caused reduced resistance to infection, emphysema, and alveolar extension in mice after one year exposure. In humans, concentrations slightly greater than 0.1 ppm (120 $\mu g/m^3$) were associated with increased incidence of lower respiratory tract infection.

A-VI.2.1.8 Ozone (O_3) (2,9)

Ozone can cause dye fading and rubber deterioration. Discomfort in humans results from levels of 100 to 200 $\mu g/m^3$ for 13 to 30 minutes. Indications are that long-term exposure to even lower levels of ozone contributes to premature aging. A concentration of 60 $\mu g/m^3$ causes injury to tobacco leaves.

A-VI.2.1.9 Sulfur

A-VI.2.1.9.1 Hydrogen Sulfide (H_2S) (2,11)

A level of 1,000 to 10,000 $\mu g/m^3$ hydrogen sulfide is associated with an increase in the incidence of decreased corneal reflex (convergence and divergence) after chronic exposure. Irritation of conjunctiva, fatigue, loss of appetite, and insomnia have been reported after chronic exposure to 10,000 to 70,000 $\mu g/m^3$ hydrogen sulfide. A level of 450 $\mu g/m^3$ is associated with increased incidence of nausea, loss of sleep, shortness of breath, and headaches following chronic exposures, while a level of only 120 $\mu g/m^3$ is associated with increased incidence of mental depression, dizziness and blurred vision.

Russian studies have indicated that infants may be particularly sensitive to exposure of H_2S at very low concentrations. Concentrations of H_2S in the 100 to 1,000 $\mu g/m^3$ range have produced a symptom complex usually manifested as undernourishment, delayed growth, general weakness, and retarded physical and neuro-physical development (e.g., infants began walking late and were slow in cutting teeth), as well as assorted gastrointestinal disturbances. Whether the general impaired development and poor health were the result of direct toxic action or were secondary to undernourishment and gastrointestinal disturbances induced by the gas, was not established. Confirmation of these studies in the western world is lacking.

Certain individuals, because they are afflicted with a particular disease, metabolic disorder, or psychological disturbance; have an enhanced susceptibility when exposed to hydrogen sulfide. Included among these high-risk categories are infants and those with eye and respiratory tract ailments, anemia, alcoholism, schizoid or paranoid tendencies, and those who have been previously exposed to H_2S.

Since the standard must protect many high-risk groups within the general population, the Illinois Environmental Health Resource Center (EHRC) has recommended a standard for gaseous hydrogen sulfide of 15 $\mu g/m^3$ (based on an 8-hour average sample) to protect the general population. This concentration, however, does not prevent the human detection of this gas at considerably lower concentrations, as the "rotten egg" odor threshold for H_2S has been reported to be as low as 0.00047 ppm (0.65 $\mu g/m^3$). In addition, no account has been taken of phytotoxic, animal, or material effects. However, based on presently available health data, the EHRC believes that the proposed standard will prevent adverse health effects from H_2S exposure in the general and high-risk populations.

A-VI.2.1.9.2 Sulfur Dioxide (SO_2) (4,9)

The MEG values for sulfur dioxide have not been determined as yet. Sulfur dioxide at 13,000 $\mu g/m^3$ combines with water to form a corrosive acid which is an eye, skin, and mucous membrane irritant. The threshold SO_2 concentration below which no injury occurs to alfalfa plants appears to be 260 $\mu g/m^3$.

Corrosion of metals by acids derived from airborne SO_2 is most important. Zinc and steel are particularly vulnerable to attack by atmospheric SO_2. Paper and leather products are strongly influenced by SO_2 and tend to disintegrate or discolor after prolonged exposure to relatively high levels of SO_2. Concrete, marble, roofing slate, mortar and limestone are subject to attack from acids derived from SO_2. Most of the concrete and limestone used in the construction of highways and buildings in the United States is not seriously affected by the present level of atmospheric SO_2. The SO_2 level and the relative humidity are the most important factors determining the corrosion rate for galvanized products. The relationship between SO_2 and damage to paint is not as clear as it is between SO_2 and corrosion of galvanized products. The threshold or minimum level of SO_2 required to produce an economic loss seems to be greater than or equal to 10 $\mu g/m^3$. For lack of better data, it is reasonable to assume a threshold level of 20 $\mu g/m^3$ before any significant loss is achieved.

A-VI.2.1.10 Tin (Sn) (2,4,7,12)

Airborne inorganic tin may be considered nontoxic (except as tin hydride, SnH_4) to most organisms, except at very high concentrations (500 $\mu g/g$ of animal for 14 months). Organic tin compounds, however, are extremely toxic to mammals, including man. A reasonable upper limit for airborne inorganic tin (except SnH_4) might be 10,000 $\mu g/m^3$. Tin hydride is very toxic and should not be tolerated at any level.

A-VI.2.1.11 Titanium (Ti) (2)

Mice were reported to succumb to air levels of 10,000 μg/m^3 titanium chloride ($TiCl_4$) which is equivalent to 2,500 μg Ti/m^3. Thus, a value of 6,000 μg Ti/m^3 could result in toxicity near the emission source if titanium is present in the form of the chloride.

A-VI.2.1.12 Vanadium (V) (2)

Workers exposed to 200 to 500 μg/m^3 vanadium have suffered negative respiratory symptoms. Eye problems have been reported at vanadium levels of 100 μg/m^3. Phytotoxicity occurs at atmospheric vanadium concentrations of 0.5 to 1.0 μg/m^3.

A-VI.2.1.13 Other Elements Having No MEGs (12)

Some elements for which toxicity information is available, but for which the MEGs have not been determined, are found in Table A-VI-6. In this table, "very toxic" indicates that the toxic effects are seen at concentrations below 1 ppm in nutrient solution of plants or microorganisms or water for aquatic animals and the dietary LD_{50} of animals occurs in the range of 1-10 mg/kg body weight. "Moderately toxic" indicates that the toxic effects appear at levels of 1 to 100 ppm in nutrient solutions for plants or microorganisms or water for aquatic animals, or the LD_{50} for animals lies in the 10 to 100 mg/kg range. "Slightly toxic" indicates that toxicity is rarely seen in plants or microorganisms or aquatic animals, and the LD_{50} for animals occurs at a dietary level of 100 to 1,000 mg/kg body weight. "Relatively harmless" indicates that the LD_{50} for animals is greater than 1,000 mg/kg.

TABLE A-VI-6. TOXICITY INFORMATION ON SOME ELEMENTS OR THEIR COMPOUNDS FOR WHICH THE MEGs HAVE NOT YET BEEN CALCULATED (12)

Element	Plant toxicity	Animal toxicity	Microorganism toxicity
Argon (Ar)	not	not	
Bromine (Br)	Elemental: very Br^-: relatively harmless BrO_x:moderately	Elemental: very Br^-: relatively harmless very as hydride	Elemental: very Br^-: relatively harmless
Calcium (Ca)	relatively harmless	relatively harmless	relatively harmless
Cesium (Cs)	relatively harmless	relatively harmless	relatively harmless
Chlorine (Cl)	relatively harmless as Cl^-, moderately to very toxic as Cl_2, ClO^- or ClO_3^-	see plants Hydride: very	see plants
Hafnium (Hf)	slightly	slightly	slightly
Helium (He)	harmless	harmless	harmless
Iodine (I)	slightly	slightly very toxic as hydride	
Iron (Fe)	moderately to slightly	slightly	slightly
Lanthanium (La)	slightly	slightly	slightly
Neodymium (Nd)	slightly	slightly	slightly
Polonium (Po)		very	
Praseodymium (Pr)	slightly	slightly	slightly

(continued)

TABLE A-VI-6. (continued)

Element	Plant toxicity	Animal toxicity	Microorganism toxicity
Radium (Ra)		the high toxicity to mammals is probably due to the radioactivity	
Radon (Rn)		the high toxicity to mammals is probably due to the radioactivity	
Rubidium (Rb)	scarcely toxic in the presence of K	see plants oxides: very	see plants
Samarium (Sm)	slightly		
Silicon (Si)	slightly	slightly, but large amounts in mammalian lungs are harmful	slightly
Sodium (Na)	relatively harmless	relatively harmless	relatively harmless
Tantalum (Ta)	slightly	slightly	slightly
Thorium (Th)	slightly	slightly	slightly
Tin (Sn)	very	very as SnH_4	
Titanium (Ti)	relatively harmless	relatively harmless	relatively harmless
Tungsten (W)	moderately	slightly	
Ytterbium (Yb)	slightly	slightly	slightly
Yttrium (Y)	slightly	slightly	slightly
Zirconium (Zr)	moderately	slightly	

Obviously, elements or their compounds which are listed as "very toxic" in Table A-VI-6 should be restricted to very low-level environmental concentrations until more specific information becomes available. Elements or their compounds listed as "moderately toxic" will probably eventually have an emission MATE greater than 4.5 $\mu g/m^3$, an effluent MATE greater than 67.5 $\mu g/m^3$, and a MATE for land-destined wastes greater than 13.5 $\mu g/g$. The ambient level goals for those elements and their compounds listed as "moderately toxic" for air probably will be greater than 0.011 $\mu g/m^3$, for water greater than 0.16 $\mu g/l$, and for soil greater than 0.03 $\mu g/g$. Elements and their compounds listed as "slightly toxic" will probably have emission MATEs greater than 45 $\mu g/m^3$, effluent MATEs greater than 675 $\mu g/l$, and MATEs for land-destined wastes greater than 135 $\mu g/g$. The ambient level goals for those elements and compounds listed as "slightly toxic" for air will probably be greater than 0.11 $\mu g/m^3$, for water probably greater than 1.6 $\mu g/l$, and for land probably greater than 0.3 $\mu g/g$. The emission MATEs for elements and their compounds listed as "relatively harmless" will probably be greater than 450 $\mu g/m^3$. The effluent MATEs will probably be greater than 6,750 $\mu g/l$, and the MATEs for land-destined wastes will probably be greater than 1,350 $\mu g/g$. The ambient level goals for those elements and their compounds listed as "relatively harmless" will probably be greater than 1.1 $\mu g/m^3$ for air, 160 $\mu g/l$ for water, and 3 $\mu g/g$ for land. Until more specific information is available, these numbers can be used as the basis for developing standards. When the actual MEGs are prepared, they will probably indicate that less stringent standards will be satisfactory.

A-VI.2.2 Organics

An assessment of the environmentally hazardous levels of the vast number of organic compounds potentially emitted by a coal liquefaction facility is beyond the scope of this work. Some organic compounds are dealt with on an individual basis in the MEGs. After careful examination no data were found indicating that stated MEG values for organic compounds known to be associated with coal liquefaction were unreasonable.

A-VI.3 Water

A-VI.3.1 Inorganics

A-VI.3.1.1 Aluminum (Al) (2)

Growth reductions in wheat and orange seedlings were reported in nutrient solutions containing 100 μg/l aluminum.

A-VI.3.1.2 Antimony (Sb) (2)

Concentrations of antimony as low as 1,000 μg/l have produced harmful effects in fish.

A-VI.3.1.3 Beryllium (Be) (2)

Some varieties of citrus seedlings show phytotoxic effects at concentrations in the nutrient solution of 2.5 to 5.0 μg/l beryllium.

A-VI.3.1.4 Boron (B) (2,7,13)

The LC_{50} for fathead minnows, (*Pimephales promelas*) was 316 μg/l for 3 days of exposure, and 52 μg/l for 5 days of exposure to boron. Although boron is an essential element for plant growth and flowering, it may exert phytotoxic effects at concentrations exceeding 1.5 μg/l.

A-VI.3.1.5 Cadmium (Cd) (2,3,7,14)

Five μg/l cadmium in drinking water of rats for one year reportedly resulted in hypertension. Reproduction of grass shrimp (*Daphnia magna*) was reduced at a cadmium concentration of 0.5 μg/l. The 7-day LC_{50} for rainbow trout (*Salmo gairdneri*) is 0.016 to 0.020 μg/l. Five months' exposure to cadmium concentrations of 0.02 to 10 μg/l increased mortality of crayfish (*Cambarus latimanus*) but had little effect on growth or temperature tolerance. In fresh water systems, 0.01 μg/l cadmium inhibited the growth of floating aquatic plants.

A-VI.3.1.6 Chromium (Cr) (2,7)

Lethal levels of chromium for algae range from 32 to 6,400 μg/l. The most sensitive marine species seems to be the oyster with a lethal level of 10 to 12 μg/l.

A-VI.3.1.7 Cobalt (Co) (2,7)

A concentration of 100 μg/l of cobalt in nutrient solutions in irrigation waters is near the threshold toxicity level of crop plants, whereas a concentration of 50 μg/l appears to be satisfactory for application on all soils. Concentrations as low as 50 μg/l inhibited the growth of small carp (*Cyprinus carpio*). At 40 μg/l, cobalt retarded the growth of algae such as *Chlorella* spp. and *Euglena* spp.

A-VI.3.1.8 Copper (Cu) (2,7,13)

In general, copper concentrations less than 1,000 μg/l have been reported as toxic to many kinds of fish, crustaceans, molluscs, insects, phytoplankton, and zooplankton. If the ambient level of 10 μg/l is realized (based on ecological effects) there should be little harm to the ecosystem.

A-VI.3.1.9 Fluorine (F) (6,7,15)

The MEGs for fluorine in water have yet to be calculated. A level of 2,000 μg/l in livestock drinking water may result in some tooth mottling. Chronic fluoride poisoning of livestock has been observed when the water contained 10,000 to 15,000 μg/l fluoride.

A-VI.3.1.10 Iron (Fe) (2,12,15)

The MEGs for ferrocene based on ecological effects, and those for all other forms of iron have yet to be calculated. Levels of more than 1,000 μg/l inorganic iron and compounds (as iron) are toxic to certain sensitive plants while animals are unaffected by levels of 100 μg/l.

A-VI.3.1.11 Lead (Pb) (2,7)

Reproductive impairment of grass shrimp (*Daphnia magna*) reportedly occurs at concentrations of 30 μg/l. Since the grass shrimp is virtually at the bottom of every food chain, a reproductive failure is considered a significant problem. Brown trout (*Salmo trutta*) are adversely affected by lead at 0.00010 μg/l in soft water, whereas in hard water the 96-hour LC_{50} value is 442,000 μg/l; this makes any interpretation essentially impossible.

A-VI.3.1.12 Lithium (Li) (2)

The most lithium-sensitive plant species studied thus far appears to be citrus, with the appearance of a slight toxicity at 60 to 100 μg/l lithium hydride.

A-VI.3.1.13 Magnesium (Mg) (2)

At 7,200 μg/l, magnesium inhibits the growth of the (Botryococcus). Magnesium is a fairly common element (2.1 percent by weight in the earth's crust) and should not be an environmental hazard. In U.S. surface waters, the magnesium concentration averages 14,300 μg/l with a range of 8,500 to 137,000 μg/l.

A-VI.3.1.14 Mercury (Hg) (2,14)

Inorganic mercury at 10 μg/l has retarded regeneration of caudal fins in the killifish (Fundus heteroclitus), but this effect was reduced when the salinity of the water was decreased or when cadmium chloride was also present in the water. Mercury concentrations over 3 μg/l (as mercury sulfate) are toxic to the eggs of salmon (Oncorhynchus nerka and Oncorhynchus gorbuscha). Biological magnification up to 27,000 times the mercury concentration in water has been reported. Fish-eating birds and mammals are affected by excessive mercury in the water because of their position at the top of the food chain. The proposed EPA 1976 Water Quality Criteria for mercury is 2.0 μg/l for health protection, 0.05 μg/l for protection of freshwater life and wildlife, and 0.10 μg/l for marine life. The NAS/NAE 1972 Water Quality Criteria recommendations for mercury were essentially identical to the EPA 1976 Water Quality Criteria.

Monomethyl mercury at 0.2 μg/l is lethal to fathead minnows in 6 weeks. Some phytoplankton are affected by organomercury levels of 0.1 μg/l.

A-VI.3.1.15 Molybdenum (Mo) (2)

The 96-hour LC_{50} for the fathead minnow (*Pimephales promelas*) is 70,000 μg molybdic anhydride/l (equivalent to 41,000 μg Mo/l). Molybdosis of cattle is associated with alsike clover grown in soils that had 10 to 100 μg/l of molybdenum in saturation extracts.

A-VI.3.1.16 Nickel (Ni) (2,7)

Nickel is very toxic to many plants especially citrus; at concentrations above 0.0005 μg/l it will inhibit plant growth. Nickel carbonyl has been reported to cause death after 30 minutes at doses of 30 μg/g animal.

A-VI.3.1.17 Nitrogen

A-VI.3.1.17.1 Cyanide (2)

Cyanide is lethal to brook trout (*Salvelinus fontinalis*) at 50 μg/l, while swimming ability is affected at levels of 10 μg/l. Free cyanide concentrations ranging from 10 to 50 μg/l (as CN^-) have proven fatal to many sensitive fishes. 10 μg CN^-/l is equivalent to 10.4 μg HCN/l. The level of hydrogen cyanide lethal to brook trout given in the above paragraph is equivalent to 91 μg/l sodium cyanide and 120 μg/l potassium cyanide. The level of CN^- lethal to more sensitive species (10 μg CN^-/l) is equivalent to 18.8 μg NaCN/l or 25.0 μg KCN/l.

The problem of additive effects is especially acute for cyanide. Undoubtedly, the cyanide anion (CN^-) causes the toxicity to the brook trout. For example, a solution of 16.67 µg/l hydrogen cyanide, 30.33 µg/l sodium cyanide, and 40.00 µg/l potassium cyanide each add 16.0 µg/l cyanide anion for a total of 48.1 µg/l cyanide (CN^-). A solution of 50 µg/l hydrogen cyanide contains 48.1 µg/l cyanide. Hence, a solution of 16.7 µg/l hydrogen cyanide plus 30.4 µg/l sodium cyanide and 40.0 µg/l potassium cyanide will kill brook trout as readily as 50 µg/l hydrogen cyanide. However, this problem can be circumvented if the effluent standard specifies the cyanide compound to be measured (e.g., "The ambient level goal shall be 5 µg/l cyanide measured as hydrogen cyanide").

A-VI.3.1.17.2 Nitrates (NO_3^-) (16)

The current MEGs do not deal with nitrates. A limit of 10,000 µg nitrate nitrogen/l of drinking water should prevent the nitrate-associated methemoglobinemia in susceptible populations including infants under three months of age. Levels two to three times this level have been reported to cause methemoglobinemia in infants.

A-VI.3.1.18 Phosphorus (P) (2)

A-VI.3.1.18.1 Phosphate

Phosphate anions are not directly toxic to man or to aquatic organisms. It is an essential nutrient (for algae as well as higher organisms) and may affect water quality by enhancement of the rate of eutrophication. A total phosphorus criterion to control nuisance aquatic growth is currently evolving. Unfortunately, no information was uncovered in the current literature on which a valid estimate could be based.

A-VI.3.1.19 Silver (Ag) (2,7)

Stickleback fish showed toxic effects at 5 μg/l. The LC_{50} for eggs of the American oyster, *Crassostrea virginica*, is 6 μg/l. Concentrations of silver as low as 2 μg/l have been found to delay development and cause deformations in sea urchins. Silver may also cause significant respiratory depression in marine teleosts after exposures to concentrations as low as 0.12 μg/l. Some aquatic organisms reportedly are sensitive to silver nitrate concentrations as low as 1 μg/l (0.63 μg Ag/l).

A-VI.3.1.20 Sulfur (S)

A-VI.3.1.20.1 Hydrogen Sulfide (H_2S) (2)

Hydrogen sulfide is toxic to bluegills at concentrations of 1 μg/l. The 96-hour LC_{50} for northern pike (*Esox lucius*) is 17 to 32 μg/l.

A-VI.3.1.21 Technetium (Tc) (17)

The MEGs for this radionuclide have not yet been calculated. This is not surprising since the only information that researchers for this study could uncover in the current literature indicated that 1.2 μg/l technetium is toxic to wheat seedlings (*Triticum aestivum*) and significantly (p less than 0.05) reduces the tissue yield of shoots in older plants. This toxicity is probably chemical in nature rather than radiological, since the amount of technetium in these experiments represents approximately 0.02 μCi/ml; this amount of radioactivity does not affect wheat seedlings. In chemical toxicity, technetium should resemble iodine, bromine, manganese, and molybdenum, because these elements occupy similar positions in the periodic table. Until more specific information becomes available, a maximum of 1.2 μg/l technetium is suggested as being low enough to prevent chemical toxicity.

A-VI.3.1.22 Thallium (Tl) (2,7)

Thallium is reported to be lethal to fish at concentrations of 0.01 to 0.06 μg/l, to aquatic insects and invertebrates at 0.002 to 0.004 μg/l, and to tadpoles at 0.0004 μg/l.

A-VI.3.1.23 Titanium (Ti) (2)

The 96-hour LC_{50} for the fathead minnow is 8,200 μg/l in soft water for titanium sulfate; this concentration is equivalent to 2,730 μg Ti/l.

A-VI.3.1.24 Uranium (U) (2)

The 96-hour LC_{50} for the fathead minnow (*Pimephales promelas*) is 2,800 μg uranyl sulfate ($UO_2SO_4 \cdot 3H_2O$)/l (equivalent to 1,600 μg uranium/l) in soft water.

A-VI.3.1.25 Vanadium (V) (2)

Flax, soybeans, and peas showed toxicity to vanadium at 500 to 2,500 μg/l in nutrient solutions. The relevance of this observation to the MATE is hard to determine, since vanadium in the effluent stream would interact with sediment and, in general, would probably be less effective when terrestrial crops were exposed to the same concentrations in soil media.

A-VI.3.1.26 Zinc (Zn) (2)

In hard water (200 mg/l as $CaCO_3$), 180 μg/l zinc reduced the fertility of fathead minnows (Pimephales promelas). Since the toxicity of zinc increases as water hardness decreases, this effect would probably occur at lower concentrations in soft water. Rainbow trout (Salmo gairdneri) eggs did not hatch in soft water at a concentration of 40 μg Zn/l. The 96-hour LC_{50} for fathead minnows is 870 μg Zn/l in soft water (20 mg/l as $CaCO_3$). Zinc concentrations of 400 to 1,600 μg/l in nutrient solutions are phytotoxic to certain varieties of soybeans.

A-VI.3.1.27 Other Effluent Elements Having No MEGs

See discussion under "AIR" for the same heading.

A-VI.3.1.28 Dissolved Solids

The MEGs for "Totals" have not been developed yet. Dissolved solids comes under this category of "Totals." The U.S. Public Health Service recommends that water containing more than 5.0×10^5 μg/l dissolved solids should not be used for drinking purposes if other less mineralized supplies are available. However, it is recognized by the U.S. Public Health Service that a considerable number of supplies with dissolved solids in excess of the recommended limit are being used without any obvious ill effects.

A-VI.3.2 Organics

As was found with organic air emissions, no data were found indicating that stated MEG values for organic compounds known to be associated with coal liquefaction were unreasonable.

A-VI.4 Solid Wastes

A-VI.4.1 Inorganic

A-VI.4.1.1 Molybdenum (Mo) (2)

Determination of the applicability of any soil ambient level goal is quite complex in the case of many elements. Molybdenum is no exception. There is an interrelationship between the molybdenum and copper requirements in the nutrition of sheep and cattle. Copper poisoning is associated with low molybdenum levels in forage, and copper starvation is associated with high molybdenum levels.

Molybdosis of cattle is associated with alsike clover grown in soils that had 10 to 100 μg/l of molybdenum in saturation extracts.

A-VI.4.1.2 Selenium (Se) (2,7,12)

The concentrations of selenium in plant tissues can reach to 1,000 times the concentration in the soil without apparent phytotoxicity. However, these concentrations of selenium in forage can be toxic to animals. A concentration of selenium between 0.04 and 2 μg/g in the diet is required to prevent selenium deficiencies in cattle, while concentrations of 4 to 5 μg/g in the diet causes selenium toxicity. Assuming a concentration factor of 1,000, forage grown in soil containing more than 0.004 to 0.005 μg/g selenium would be toxic to foraging animals, while soils containing 4.0×10^{-5} to 0.002 μg/g would be deficient. Since plants grown in regions poor in selenium generally concentrate selenium more efficiently, this soil level may be sufficient to prevent selenium deficiency. Considering that the dietary concentration of selenium which results in deficiency, and the dietary concentration of selenium which results in toxicity differ only by a factor of two, and that the dietary concentration depends on the plant concentration factor and the soil concentration, the determination of a general soil ambient level goal would be difficult. However, the ambient level goal of 0.003 μg selenium per gram of soil appears reasonable.

A-VI.4.1.3 Other Solid Waste Elements Having No MEGs

See discussion under "AIR".